Scientific thought IN THE American colleges

1638-1800

Q181
.H81

LIBRARY OF PRINCETON
SEP 30 1947
THEOLOGICAL SEMINARY

Q181
.H81

Digitized by the Internet Archive
in 2024 with funding from
Princeton Theological Seminary Library

https://archive.org/details/scientificthough00horn_0

THEODORE HORNBERGER

THE UNIVERSITY OF TEXAS PRESS
AUSTIN: 1945

LIBRARY OF PRINCETON
SEP 30 1947
THEOLOGICAL SEMINARY

Scientific thought IN THE American colleges

1638-1800

This volume is published as Project
No. 67 of the
University Research Institute

COPYRIGHT, 1946
BY
THE BOARD OF REGENTS
OF
THE UNIVERSITY OF TEXAS

Preface

The essay which follows is a by-product of a larger investigation of scientific thought in North America before 1800, upon which I have been engaged for more years than I care to admit. The unit which it forms grew so large, and appeared to have such general interest, that I have thought it wise to publish what I have brought together here. Many readers, I am sure, will be able to correct errors and to indicate areas in which further study is desirable, and I shall be happy if they will do so. I hope, however, that these pages will prove useful to the special student and moderately entertaining to the general reader. For the sake of the latter I have, after considerable debate, placed the notes, which form a fairly extensive bibliography of the subject, at the end, lest they engulf the text.

A few of the many obligations I have incurred in the gathering of this material have been acknowledged in the notes. I cannot but express my gratitude, however, to the following persons, each of whom will know how great is my debt: Mr. and Mrs. James Inglis, Howard Mumford Jones, Samuel Eliot Morison, Allyn B. Forbes, Louis B. Wright, Merle Curti, C. F. Arrowood, Frederick Eby, Donald Coney, L. C. Karpinski, and Frederick E. Brasch.

Austin, June 14, 1945 THEODORE HORNBERGER

Contents

I
Values in the History of Science 1

II
The First American Colleges 5

III
Entrance Requirements 16

IV
The Curriculum 22

V
Teachers, Methods, and Textbooks 35

VI
Libraries 76

VII
The Effects 79

Notes 89

Index 105

Illustrations

Plate illustrating balances of different sorts, from J. T. Desaguliers' *Course of Experimental Philosophy,* London, 1734 (by courtesy of The Huntington Library, San Marino, California) 46

John Winthrop (1714–1779), Hollis Professor of Mathematics and Natural Philosophy, Harvard College, 1738–1779, from an engraving of a portrait by John Singleton Copley in the possession of Harvard University (by courtesy of the Colonial Society of Massachusetts) 50

Plate illustrating the principle of the center of gravity, from Desaguliers' *Course* (by courtesy of The Huntington Library) 58

Plate illustrating movement of pendulums, etc., from Desaguliers' *Course* (by courtesy of The Huntington Library) 63

I

Values in the History of Science

In the realm of ideas few things are quite so dead as is outmoded science. Political philosophies have a way of reappearing in modern dress; ethical and religious concepts frequently linger in one stratum of society long after they have disappeared from another; fashions in literature and the arts come and go and come again. The discredited scientific hypothesis, however, is peculiarly useless, and no one should be much surprised that most persons who work upon the frontiers of knowledge have little inclination, even when they have the time, to explore the blind alleys into which their predecessors wandered.

Scientists are often convinced, therefore, that there is no great value in the history of science. They respect the great discoveries, the high points in the advancement of knowledge, and they pay tribute to the leaders who have stated with apparent finality the law which prevails in one corner or another of nature. With the state of knowledge prevailing at a given point in the past, or with the relation of science to the other facets of the intellectual life of a particular period they are only rarely concerned.

The historian of ideas, however, is forced to deal with the problem of why men have accepted certain concepts and rejected others, as well as with the puzzle of the effect of accepted

notions upon men's actions and their all-over view of the world in which they lived. To him it is sometimes no great matter whether men's ideas are sound or not, nor is he much absorbed in the acceptability or completeness of their world-views. His task is to present, upon a scale far larger than that which measures the lives of individuals, the story of human trial and error, not merely because that story is sometimes quaint and amusing, but because the life of the intellect is shaped in curiously persistent patterns. To know them is one way both to use the experience of the past for what it may be worth in the present and to come to the humbling yet exhilirating realization that the lifetime of one man or of one generation can never be more than a point or stage in the flux of intellectual history.

The subject of the present study will seem to some readers particularly trivial. If there was any scientific thought in the American colleges before 1800, it must have been of little account. Were not those colleges created primarily if not solely for the training of clergymen? Was not Benjamin Franklin, the only first-rank American scientist of that period, self-educated? Were not the higher levels of education dominated, almost within the memory of living men, by those who believed the study of the classical languages and literatures the only sure route to educational salvation? What could be more futile than a recital of the superstitions and misinformation which passed for science in the tiny academic world of the seventeenth and eighteenth centuries?

To such questions there can be only one answer—an invitation to suspend final judgment until the facts are in. It is possible that the purposes and the nature of the colleges before 1800 have been misunderstood. It is possible, indeed, that the

record of the American colleges in the teaching of scientific subjects is more distinctive than has been generally realized.

Most historians are agreed that the advancement of scientific knowledge in Europe between 1600 and 1800 was not, in the main, the work of the universities. Proud of their medieval heritage, and controlled largely by churchmen, the English and continental institutions of higher learning were markedly hesitant about welcoming new subjects and techniques, despite the presence in their halls of many enthusiastic scientists. Their awareness of the importance of the New Science can be demonstrated, as R. T. Gunther has demonstrated it in his series of volumes on *Early Science at Oxford,* but there is little reason to object to Professor Wolf's conclusion that "the vast majority of the pioneers of modern thought were either entirely detached from the Universities, or were but loosely associated with them."[1] Leadership in the sciences was seized by the coöperative societies which were founded in most of the nations of western Europe, beginning with the formation of the Academia Secretorum Naturae at Naples in 1560. State aid, the patronage of men of wealth, and the pooled resources of their own members gave the scientific associations outlets for publication and rewards in prestige beyond what even the wealthiest of universities was prepared to offer. Sir Isaac Newton, therefore, is more often identified with the Royal Society of London than with Trinity College, Cambridge; Linnæus with the Academy of Sciences at Upsala rather than with its university. The history of the major contributions to science in the period is to be read in such series as the *Philosophical Transactions,* not in curricula, professorships, and academic foundations.

The little colleges of British America could scarcely be expected to achieve a leadership which their transatlantic models had virtually abdicated. Until recently, however, relatively

little has been known about their intellectual atmosphere, and perhaps they have been dismissed too lightly. As the older historians were interested mainly in political and constitutional development, so were the annalists of the colleges largely absorbed in the details of charters, the constitution of governing boards, internal organization, and the more striking achievements of administrators.[2] The new emphasis upon cultural history, which has attracted many scholars of the present generation, has already resulted in large stores of new information about what went on in the minds of the teachers and students of past centuries. No doubt much more will come to light, but there is enough already to justify a fresh examination of the attitude of the colleges toward science.

How did the colleges adjust themselves to one of the great intellectual movements of the age of their foundation? What effect, if any, did they have upon the thought of a rapidly developing civilization? Such questions may be asked with more confidence of reasonably adequate answers than has heretofore been justifiable. They are, moreover, not merely antiquarian, but must be asked persistently by all who are moved to reflect upon the function and process of higher learning.

II

The First American Colleges

In 1803 the Rev. Samuel Miller of New York published, in two volumes, *A Brief Retrospect of the Eighteenth Century.* A dozen pages at the end of his second volume is the nearest thing we have to a directory of American colleges at that stage of their development. Miller had evidently tried to obtain by correspondence authoritative information on the date of founding, the faculty, the number of students, the estimated annual expense, the size of the library, and the philosophical (which is to say, scientific) apparatus of each college in the United States. He was able to list twenty-seven institutions in seventeen states, Delaware being the only state then in the Union without some kind of chartered college. Some of the foundations named by Miller existed only upon paper, and a number of others were not actually offering college-level work, but his list is very nearly complete,[1] and, as he himself realized, excellent testimony to the seriousness with which Americans regarded higher education.

Schematically arranged, with some modifications of his order, Miller's directory is as follows:

Maine: Bowdoin.
New Hampshire: Dartmouth.
Vermont: Middlebury.
Massachusetts: Harvard, Williams.
Rhode Island: Rhode-Island (later Brown).

Connecticut: Yale.
New York: Columbia, Union.
Pennsylvania: University of Pennsylvania, Dickinson, Franklin (later Franklin and Marshall).
New Jersey: Nassau-Hall or the College of New-Jersey (better known as Princeton).
Maryland: University of Maryland, consisting of St. John's and Washington; Catholic College of Georgetown; Cokesbury.
Virginia: William and Mary, Hampden-Sidney.
North Carolina: University of North Carolina.
South Carolina: Winnesborough, Charleston, Cambridge, Beaufort.
Georgia: University of Georgia.
Kentucky: Transylvania.
Tennessee: Greenville (later Tusculum).

Eleven of these twenty-seven institutions may be dismissed at once in an investigation of cultural patterns before 1800. Bowdoin, although incorporated in 1794, held no classes until 1802.[2] Middlebury graduated its first class in 1802; it was the outgrowth of a grammar school founded in 1797 and chartered as a college in 1800.[3] Dickinson and Franklin, in Pennsylvania, although incorporated in 1783 and 1787 respectively, had not attained before 1800 the stability which they were to have later.[4] Cokesbury, at Abingdon, Maryland, founded by the Methodists in 1784 and named after Thomas Coke and Francis Asbury, the first bishops of that church in the United States, had actually ended its twelve years of precarious existence in 1796, some time before Miller wrote.[5] There appears to be no available information on the history of Georgetown in the eighteenth century.[6] Not one of the four South Carolina colleges was really operating above the secondary school level in 1800; Cambridge and Beaufort were probably never more than names; Winnesborough became in course of time the Mount Zion Institute, a famous preparatory school; the reputa-

tion of Charleston was still to be made.[7] The University of Georgia, finally, although founded on paper in 1785, did not open its doors to students until the beginning of the nineteenth century.[8]

The other sixteen colleges deserve fuller attention, although only eight of them have enough of a history prior to 1800 to make it proper to speak of their cultural influence by that date. It is most convenient, probably, to present Miller's information, with correction where that is necessary, in the chronological order of actual classroom instruction. As will appear, the date of the first classes very seldom corresponds with that of the legal foundation.

HARVARD[9]

Miller gave 1638 as the date of the founding of Harvard. That year saw the beginning of teaching under the charter of 1636. The faculty at the end of the eighteenth century consisted of the president, four tutors, and six professors, in the fields of divinity, mathematics and natural philosophy, rhetoric and oratory, anatomy and surgery, the theory and practice of physic, chemistry and materia medica. There were, Miller reported, between 180 and 200 students, the annual expense being about $120. The library of 13,000–14,000 volumes was the largest in the United States excepting one (presumably the collection of the Library Company of Philadelphia). The scientific apparatus was "generally said to be the best in America."

YALE[10]

Yale, incorporated in 1701 as the Collegiate School of Connecticut, began its actual instruction in 1702, about eight years before William and Mary, chartered in 1693, was doing college

work. Miller reported a faculty of seven—the president, three tutors, and professors of mathematics and natural philosophy, divinity, and oriental languages. Its student body of 217 in 1801 was believed to be the largest in the United States and it was possible to squander from $120 to $150 in a year at New Haven. The library, which had suffered somewhat in the Revolution, numbered between 3,000 and 4,000 volumes, and the apparatus was "considered among the best in our country."

WILLIAM AND MARY[11]

William and Mary, incorporated in 1693, was no more than a secondary school until about 1710. By the end of the century, according to Miller, its faculty consisted of the president, who also served as professor of moral and natural philosophy, and five other professors, in mathematics, ancient languages, modern languages, law, and chemistry. There were fifty-three students in 1801, a library of 3,000 volumes, and apparatus which "when procured in 1768, was well chosen, and tolerably complete. It cost, at that time, between 2000 and 3000 dollars. Having been in constant use for more than 30 years, it stands in need of repairs, and is less complete than at first." Miller also provided a description of the textbooks then in use. He did not, however, give any account of the various changes in the William and Mary curriculum which, as will appear, have unusual interest.

PRINCETON[12]

The College of New-Jersey, founded in 1746 and settled at Princeton in 1756 after several years of instruction elsewhere, had in 1803 a president, three tutors, and three professors, in languages, divinity, and mathematics, natural philosophy, and chemistry. Miller reported that there were 150 students, and the

annual expense was between $150 and $170, which made it, if his tabulation may be trusted, the most expensive college in the country. The library was said to be "small," the apparatus "respectable." Princeton had been among the chief sufferers from the destruction of the Revolutionary War.

COLUMBIA[13]

Columbia, founded as King's College in 1754, was one of the few institutions where college teaching actually preceded the granting of a charter. It had, by the end of the century, one of the most complicated structures of any American college. The faculty of the college proper consisted of the president and professors in four extensive fields; moral philosophy, logic, rhetoric, and belles-lettres; the Greek and Latin languages and Grecian and Roman antiquities; mathematics, natural philosophy, chronology, and geography; and chemistry. In addition the medical school had a dean and four professors, in the fields of anatomy and surgery, the institutes of medicine, obstetrics, and materia medica and botany. There were 125 matriculated students in the college, and others in the medical school; Miller attempted no estimate of the expense of a year in New York City. The library contained 3,000 volumes, and the apparatus was "among the best in the United States." Miller, however, failed to record the intricacies of Columbia's teaching history; they are, as will appear, of considerable importance.

PENNSYLVANIA[14]

According to Miller, the University of Pennsylvania was founded in 1791, when the College of Philadelphia, formed in 1753, was combined with another institution established after the Revolution. The most recent historian of the university

begins his story in 1740, with the foundation of a charity school from which developed the Academy of Philadelphia, in which Benjamin Franklin interested himself in 1749. Actual college classes appear, however, to date from 1755, and the first commencement was held in 1757. Like Columbia's, the internal structure was highly involved. Miller reported that the faculty was composed of the provost, who was also professor of natural philosophy, the vice-provost, who held the chair of logic and moral philosophy, and four other professors, in the Greek and Latin languages, mathematics, English and belles lettres, and oriental literature. The medical school, moreover, had professors in four fields: anatomy; the institutes and practice of medicine; materia medica, natural history, and botany; and chemistry. In 1803 there were 160 students, most of them in the medical school, which was the largest in the country. The library numbered 1,000 volumes; the apparatus was "tolerably good." Pennsylvania, as will appear, had a record of a great deal of experimentation in its classroom instruction, although it probably was somewhat less venturesome than Columbia.

BROWN[15]

Rhode-Island College, which became Brown University early in the nineteenth century, was chartered in 1764 and began work in the year following. Miller reported a faculty of five, the president, three tutors, and professors of law and mathematics and natural philosophy. There were 107 students in 1801, the annual cost being about $100. The library contained about 3,000 volumes, and the apparatus was "tolerably complete," thanks to the recent generosity of Samuel Elam, Esq., of Newport. Brown's professorships, as will appear, were somewhat outside the regular framework of instruction.

DARTMOUTH[16]

Dartmouth, the history of which begins with an Indian school founded by the Rev. Eleazar Wheelock at Lebanon, Connecticut, in 1754, was chartered as a college in 1769 and began its work at Hanover in 1770. In Miller's time it had a faculty of six, including the president, two tutors, and professors in mathematics and natural philosophy, the Latin and Greek languages, and chemistry and medicine. There were 140 students in 1801, expending annually about $100. The college library numbered about 3,000 volumes, and the apparatus was regarded as "sufficient for a common course of experimental philosophy."

WASHINGTON[17]

Washington College, at Chestertown, Maryland, goes back to an academy organized in 1706, but it was incorporated as a college in 1782 and granted its first degrees one year later. Miller had no information on its condition, but the college is noteworthy for the patronage of George Washington, whose name it took, and for its close connection with the College of Philadelphia, whose former provost, the Rev. William Smith, became its first president. It created at least one professorship, in natural philosophy and logic, in 1782.

HAMPDEN-SIDNEY[18]

Miller gave 1774 as the date of founding of Hampden-Sidney in Virginia; other authorities say 1775 or 1776. Originally Prince Edward Academy, it became Hampden-Sidney in 1777, and was made a college by a legislative act in 1783. College instruction presumably began at that time. Miller reported between sixty and seventy students, a library of 500 volumes, and "small" apparatus.

ST. JOHN'S[19]

St. John's at Annapolis, sister college to Washington in the first University of Maryland, has an even longer history, going back to the foundation of King William's School in 1696. It was created a college in 1785, held its first college classes in 1789, and graduated its first class in 1793. Miller reported a faculty of three, but there is some likelihood that it was larger. The first principal held the chair of mathematics; there were also professorships in languages and grammar. In 1801, according to Miller, there were ninety students, a "moderately large" library, and "only tolerable good" apparatus.

WILLIAMS[20]

Williams, Miller reported, was founded in 1793, the date at which it was chartered as a college. The free school at Williamstown from which it developed had been established in 1791, on the basis of the will of Col. Ephraim Williams, who had died in 1755. The first commencement was held in 1795. Of all the smaller colleges, Williams perhaps grew most remarkably. In 1800 there were ninety-three students, a faculty of five (the president and four tutors), a library of 600 volumes with the two literary societies having about 300 more, and apparatus described as "small; but well selected and good, so far as it goes. A good *Telescope,* and some other articles are much wanted to render the collection tolerably complete." A year's study cost about $100. From the first Williams modeled its curriculum upon that of Harvard. Although Miller did not mention it, the college appears to have had a professorship in the French language between 1795 and 1799.

TUSCULUM[21]

Greeneville College in Tennessee, which later merged with Tusculum and eventually took the latter name, was founded in 1794 and, since it developed from two previously organized academies, probably began instruction that same year. Miller reported that the president and one other professor taught about twenty students, with a library of 2,000 volumes and "good" apparatus. Its location in the mountains of eastern Tennessee perhaps explains its relative obscurity.

NORTH CAROLINA[22]

The University of North Carolina has a good claim to rating itself the oldest of American state universities. Provision for its foundation was made in the state constitution adopted in 1776. It was not chartered, however, until 1789, was not located at Chapel Hill until 1792, and held no classes until February, 1795. Miller said that he knew no particulars; there are, however, several extant statements concerning its curriculum and instruction before 1800.

UNION[23]

Union was founded, as Miller stated, in 1795, although the academy at Schenectady from which it sprang had been operating for about seven years. Its faculty was organized and classes begun in October, 1795, the first Commencement being two years later. It had in 1801 a faculty of at least four—the president, two tutors, and a professor of mathematics and natural philosophy. Authorities other than Miller speak also of a professor of the Latin and Greek languages. Its student body at that time numbered forty-three. The library contained 800 volumes, and the apparatus was "respectably large and good."

TRANSYLVANIA[24]

Transylvania, the most ambitious of the early western universities, was founded late in 1798 by the union of two academies. It eventually became, after many vicissitudes, the University of Kentucky. Although it had barely begun operation by 1800, Miller reported a faculty of six: the president, who was also professor of logic, metaphysics, moral philosophy, and belles lettres, and professors in the following fields: mathematics, natural philosophy, astronomy and geography; law; the Greek and Latin languages; medicine and surgery; and chemistry. There were seventy students in 1801, nineteen of them in law and six in medicine. The expenses were estimated at from $80 to $100 per year. The college library numbered 1,300 volumes, and the apparatus was "respectable."

So much for the over-all picture. It will be noted that only eight colleges were in active operation before 1780, and, as a matter of fact, most of the story of collegiate training prior to 1800 must be told in terms of those eight: Harvard, Yale, Brown, and Dartmouth in New England; Columbia in New York; Princeton in New Jersey; Pennsylvania at Philadelphia; and William and Mary in Virginia.

It is profitable, moreover, to see the whole in three parts, or stages, because of changes which, as will appear, came somewhere about 1690 and 1740. The discussion which follows will deal, therefore, with the teaching of science in three main periods; (1) a formative period of about fifty years, extending from 1638, when instruction began at Harvard, until about 1690, when scientific studies underwent a marked change at that institution; (2) a transition period of another half century, or from 1690 until approximately 1740, in which there were striking developments both at Harvard and at its two younger

rivals, Yale and William and Mary; and (3) finally, a period of established pattern, extending through the last sixty years of the eighteenth century, and during which the sciences were handled with surprising similarity both in the older colleges and in those newly established. It may be taken for granted that the position of the sciences was everywhere strengthened during the succeeding century.

III

Entrance Requirements

It is logical to inquire first about the relation of the colleges to the preparatory schools, a relation, by the way, which still baffles many college officers. What were the entrance requirements?[1] They provide the first and the simplest key to the trend of the times.

The question can be answered very briefly. In the formative and transition periods, that is to say before 1740, nothing was demanded of prospective freshmen except knowledge of the ancient languages. In the period of established pattern, however, elementary arithmetic was generally, although not universally, added. The change is not impressive, but its details have considerable interest as a guide to the forces which were making themselves felt.

Harvard set the fashion in its laws of 1642:

> When any Schollar is able to Read Tully or such like classicall Latine Authour ex tempore, and make and speake true Latin in verse and prose *suo (ut aiunt) Marte*, and decline perfectly the paradigmes of Nounes and verbes in the Greek toungue, then may hee bee admitted into the Colledge, nor shall any claime admission before such qualifications.[2]

The laws of 1655 expanded the requirement somewhat by specifying Virgil as well as Cicero and demanding the ability to

> Construe and Grammatically to resolve ordinary Greeke, as in the Greek Testament, Isocrates, and the minor poets, or such

like, having withall meet Testimony of his [i.e., the applicant's] towardlinesse.[3]

Yale, in laws dating from 1726, likewise demanded an examination to show expertness

in both ye Greek and lattin Grammer as also Grammatically Resolving both lattin and Greek Authors and in making Good and true lattin.[4]

And William and Mary, whose statutes were first printed in 1736, prescribed

an Examination before the President and Masters, and Ministers skilful in the learned languages; whether they [i.e., the graduates of the grammar school] have made due progress in their Latin and Greek. . . . And let no Blockhead or lasy Fellow in his Studies be elected.[5]

Many a youngster, faced with such requirements, was prepared for college at home, or in the study of the village minister, and it is not too great a strain of credulity to understand the precocity of Cotton Mather, who was a freshman at Harvard when he was twelve, and of John Trumbull, who passed his entrance examination for Yale at the age of seven. The effect upon the lower levels of education is clear from the experience of Benjamin Franklin. His father, as every reader of the *Autobiography* will recall, was originally minded to give his tenth son as a tithe to the church and accordingly sent him to Latin school. Discovering, however, that he could not afford the expense of a college education for Ben, he withdrew him after about a year and sent him to Mr. George Brownwell to learn writing and arithmetic. In other words, "practical" subjects were ordinarily taught privately before the second quarter of the eighteenth century, by the tutors whose advertisements offering instruction in business mathematics, surveying, and

navigation may be found in many of the early newspapers. A typical example is the following from the *Boston News-Letter,* No. 258, for March 21–28, 1709:

> Reading, Writing, Arithmetick, Merchants Accompts, Geometry, Trigonometry, Plain and Sphaerical Dyalling, Gauging, Astronomy and Navigation are Taught: And Bonds, Bills, Indentures, Charter-parties, &c. are Drawn; and Youth Boarded, in *Cross-street, Boston.* By *John Green.*

The variety of what went on in some such establishments is suggested by the advertisement of Franklin's own teacher, in No. 463 of the *News-Letter,* February 23–March 2, 1712:

> At the House of Mr. *George Brownwell*, in Wings-Lane, Boston, is Taught, Writing, Cyphering, Dancing, Treble Violin, Flute, Spinnet, &c. Also English and French Quilting, Imbroidery, Florishing, Plain Work, marking in several sorts of Stiches, and several other works, where Scholars may board.

The first sign of recognition by the colleges of anything other than the classical languages appears in the laws adopted at Yale in 1745. Applicants, say these rules,

> shall be found able Extempore to Read, Construe and Parce Tully, Virgil and the Greek Testament: and to write True Latin in Prose, and to understand the Rules of Prosodia, and Common Arithmetic and shall bring Sufficient Testamony of . . . Blameless and inoffensive Life.[6]

Common arithmetic and the "character test" come in at the same time.

The younger colleges tended to follow Yale's example. Princeton's requirement in 1746 was wholly classical, but arithmetic to the rule of three (that is to say, proportion) was added in 1760.[7] When Columbia was about to open, the president advertised in the newspapers that prospective students should be able to read well, write legibly, know the five first

rules in arithmetic (i.e., as far as division and reduction), and of course, have the Latin and Greek necessary to read Cicero's orations, the first books of the *Aeneid,* and some of the Gospel of St. John.[8]

The different attitude appears most conspicuously at William and Mary, where, in 1770, the Visitors authorized—we are told that their action was "against the protest of the faculty"—that

> All such youth, whether resident in or out of the College, who have acquired a competent knowledge of common or vulgar Arithmetic, & whose Parents or Guardians may desire it, be received into the Mathematical school.[9]

Nine years later, in an era of reorganization, William and Mary set up a striking statement of its degree requirements and announcing a genuinely startling policy for admissions. "The Doors of ye University," President Madison wrote to President Stiles of Yale,

> are open to all, nor is even a knowledge in ye ant. Languages a previous Requisite for Entrance. The Students have ye Liberty of attending whom they please, and in what order they please, or all ye diffr. Lectures in a term if they think proper.[10]

Thomas Jefferson, a member of the Board of Visitors at the time, had a part in the development of this liberal policy.[11]

To the end of the century, however, the classical languages were doubtless the only really important qualification at most institutions. Harvard, indeed, seems not even to have asked for arithmetic until 1803, and it is possible that Columbia may have forgotten it by 1801.[12] Williams did not demand arithmetic in 1793, although it did allow a student to substitute French for the classical languages if he was "able to read and pronounce, with a tolerable degree of accuracy and fluency, some approved French author."[13] The word "tolerable" appears to have been extraordinarily useful in the eighteenth century.

North Carolina demanded only the classical languages in 1795.[14] Dartmouth and Brown, on the other hand, followed the practice at Yale.[15]

In an age which honored Newton and Laplace to the verge of adoration, the colleges asked very little in the sciences from the lower levels of education. Some freshmen, however, doubtless had a wider acquaintance with scientific subjects than the entrance requirements suggest, especially if they came from the academies which were rapidly replacing the traditional grammar schools. The plan of education adopted in 1786 at Wilmington, Delaware, for example, provided for a professor of mathematics to teach the two upper classes, at seven shillings and sixpence per quarter extra. The junior class was to learn

> all the rules of arithmetic, vulgar and decimal, the four rules of Algebra, and the method of solving simple Equations, Euclid Book I, Geography, and the use of the globes,

the senior class to study

> Euclid, Trigonometry (plain and spherical), Surveying and Navigation, the 'principles also of Astronomy and of the Newtonian System, the Solution of quadratic equations, and the principles of the conic sections.[16]

In the same year such studies were encouraged by a meeting of prominent scientists in the Academy building, at which Benjamin Franklin is said to have performed electrical experiments and David Rittenhouse and James Madison to have made astronomical observations from the cupola.

Nor was the Wilmington Academy unique. Timothy Dwight taught algebra, geometry, geography, and even Newton's *Principia* to some of his students in the academy at Greenfield Hill, Connecticut, in the seventeen-eighties,[17] and in the nineties the College of Charleston, although not yet offering work on

the college level, sponsored a lecturer in chemistry and popular courses in natural philosophy.[18] In 1792, according to Jeremy Belknap, Phillips Academy at Exeter, New Hampshire, was regularly instructing in "the learned languages, the principles of geography, astronomy, mathematics, and logic; besides writing, music, composition and oratory."[19]

These, however, were late developments. By and large it is safe to assume that the average college freshman before 1800 knew less mathematics than the average high-school freshman today, and was almost never on speaking terms with biology or chemistry or physics. If he had come into contact with the scientific thought of his time he was distinctly unusual.

IV

The Curriculum

In the colleges themselves, the sciences were never entirely neglected. It is possible, indeed, to estimate with fair precision the proportion of time allotted to scientific subjects in some institutions, and it appears that this proportion gradually increased.

Once in college, the American student ordinarily spent four years acquiring his B.A. degree. Occasionally there were three-year programs or other irregularities. President Henry Dunster of Harvard, for example, laid out a three-year scheme, perhaps in emulation of the English universities, in 1640; it was abandoned in 1652. Provost William Smith, at Pennsylvania, instituted a three-year program in 1756 which lasted about seventy years, and was the model for the curriculum at Washington College in Maryland. And at William and Mary, in 1779, it was decided to adjust the length of the program to the needs and achievement of the individual student. In general, however, the four-year program developed with amazing uniformity, and it has, of course, remained characteristic of the American college.

THE FORMATIVE PERIOD

The Harvard curriculum of 1640–1652, minutely described in *New England's First Fruits* (London, 1643), has some unusual features, but it is chiefly useful because it permits some statistical calculation of the stress upon the sciences in the first or formative stage of development.

The president, carrying practically all the burden of teaching by himself, planned a school year divided into four terms or quarters, and a school day of six sixty-minute periods. If one takes the liberty of applying the present-day measure of an "hour" of credit for attendance on one class once a week for one term, the student under Dunster's program may be said to have accumulated 140 hours of credit in his three years of work. The time relation of the various subjects may then be indicated as follows:[1]

Logic and Disputations (in Latin)	30 hours
Greek	24
Hebrew, Aramaic, and Syriac	24
Rhetoric and Declamations	24
Divinity and Commonplaces	16
Ethics and Politics	8
Arithmetic and Geometry	6
Physics	2
The Nature of Plants	2
Astronomy	2
History	2

Scientific problems of a broad, general nature were doubtless encountered in the study of the classics, or were dealt with in the disputations and syllogistic exercises, but as far as class-work went less than nine per cent of the time was allotted to the sciences. The freshmen studied physics two hours each week in their fourth term, and botany one hour per week in the first and fourth terms. Seniors gave two hours each week for three terms to arithmetic and geometry, and in their fourth term recited in astronomy.

The change to a four-year course at Harvard about 1652 appears to have resulted from the discovery that one year was not enough for an adequate foundation in logic and rhetoric. An incomplete statement of the curriculum four years later

suggests that the freshman year was then spent largely on the languages, the sophomore year on logic, the junior year on ethics, and the senior year on metaphysics and mathematics, with the languages, rhetoric, oratory, and divinity running concurrently throughout the course.[2] Neither physics nor botany is mentioned, but there is evidence that the former, at least, continued to be studied.

THE TRANSITION PERIOD

A third view of the Harvard curriculum, although drawn up in 1723, gives what is thought to be the scheme of studies established late in the seventeenth century.[3] It represents the second or transition period in scientific studies. By that time the freshman's preparation in Latin had been found inadequate. In the first year, therefore, Cicero and Virgil were reviewed, together with Isocrates, Homer, and the Greek Testament; rhetoric was begun, and, in the latter part of the year, Hebrew and logic. In the second year, Greek, Hebrew, and logic were continued, and physics added. In the third year, physics was continued, and ethics, metaphysics, and "a System of Geography" studied, the last-named subject being here mentioned for the first time. In the fourth year, a general review of grammar, logic, and physics, was accompanied by study of arithmetic, geometry, and astronomy. All classes spent their Saturdays on divinity, and devoted some time to disputations.

Science seems to have occupied little if any more of the student's time at Harvard in 1700 than it had in 1640. There was perhaps, as will appear more clearly when the teaching is examined, a little more emphasis upon physics, but not much. The minimizing of mathematics, and the teaching of arithmetic and geometry to seniors are, from our perspective, quite surprising. Samuel Eliot Morison has noted that as late as 1725

Harvard seniors were spending a month in the study of arithmetic before undertaking Euclid, and that there is no trace of algebra in the curriculum until 1721.[4] His explanation is that when Dunster was an undergraduate arithmetic and geometry were regarded by Cantabrigians as beneath the dignity of scholars. Whatever may have been the reason, Harvard was very slow to regard mathematics as a fundamental tool, or to make it an integral part of the training of underclassmen. The elementary branches do not seem to have been required of freshmen and sophomores until 1787.[5] And yet, as will be seen, Harvard held an enviable position of leadership in mathematics for a good part of the eighteenth century.

The earliest generous recognition of the sciences in America came at William and Mary. Still little more than a grammar school, that institution in 1711 appointed a Mr. Le Fevre (his first name is unknown) as professor of natural philosophy and mathematics.[6] Le Fevre was not only William and Mary's first professor, but he was also the first man to hold a chair of science in any American college. Unfortunately he was immediately in trouble, thanks, so Governor Spotswood said, "to an idle hussy he brought over with him" from London. Although the governor promptly shipped this distraction back to England, Le Fevre distinguished himself only by drunkenness, negligence of his duties, and some unspecified "irregularities" for which he was discharged in 1712. There is no record of a successor until 1717, when the Rev. Hugh Jones (1670?–1760*)[7] was appointed. Jones probably offered competent instruction for a time, but we know nothing of the curriculum at William and Mary until 1727.

At that time statutes were adopted establishing three schools: (1) a grammar school, wherein four years of Latin and two of Greek were prescribed; (2) a philosophical school, correspond-

ing roughly to our present-day arts college; and (3) a divinity school. The philosophical school was to have a professor of moral philosophy (to teach rhetoric, logic, and ethics) and a professor of natural philosophy and mathematics (to teach physics, metaphysics, and mathematics). For a time it may have had a shortened program for the B.A. degree, but by 1758 it had adopted the usual four-year course.[8]

That plans at William and Mary were laid with forethought appears from an unusual provision in the statutes, to which governing boards might even today be sometimes referred:

> Forasmuch as we see now dayly a further Progress in Philosophy, than could be made by Aristotle's Logick and Physicks, which reigned so long alone in the Schools, and shut out all other; therefore we leave it to the President and Masters, by the Advice of the Chancellor, to teach what Systems of Logick, Physicks, Ethicks, and Mathematicks, they think fit in their Schools. Further we judge it requisite, that besides Disputations, the studious Youth be exercised in Declammations and Themes on various Subjects, but not any taken out of the Bible. Those we leave to the Divinity School.[9]

In the long run, however, events at William and Mary proved less important than the transition at Harvard, which is most clearly marked by the foundation of the Hollis professorship of mathematics and natural philosophy in 1727. Thomas Hollis of London, who six years before had endowed a chair in divinity at Harvard, was now persuaded to anticipate one of the provisions of his will and transfer £1,200 sterling to the college.[10] The persuader was a young man named Isaac Greenwood (1702–1745*) of the Harvard class of 1721, who had gone to London after his graduation to prepare for the ministry.[11] There he pursued an interest in science by attending the lectures of various popularizers of Newtonian natural philosophy, and so impressed Hollis with his zeal that that benefactor believed

he had found the right man for the proposed chair at Harvard. Before the arrangements were completed, however, Hollis was forced to write sorrowfully to friends in New England that Greenwood had left London suddenly and without saying good-bye, forgetting also a little matter of some £300 in debts, accumulated "in a ramble of a few weeks" for such luxuries as pearl-colored stockings.[12] Despite this foreshadowing of irresponsibility, the Harvard corporation, fearful that Hollis might exercise his right of appointment and name a Baptist to the chair, elected and installed Greenwood. He lasted longer than Le Fevre had at Williamsburg, but ten years later, after a long series of attempts at reform and discipline, he too was removed for intemperance.

Harvard did not follow the example of the English universities and allow its endowed professors to go their own way outside the framework of the curriculum. Juniors and seniors were required to attend Greenwood's lectures and acquire some conception of Newtonian theories.[13] The new professor, moreover, quickly improved the quality of the work in mathematics. He was the author of the first arithmetic published by a native American, in 1729, and at about the same time prepared for his classes in algebra a manuscript textbook, of which two students' copies survive.[14] Thanks largely to Greenwood, the attitude toward "practical" subjects at Harvard changed quite markedly.

THE PERIOD OF ESTABLISHED PATTERN

There is no official account of the curriculum at Yale until 1745. At that time freshmen studied "the Tongues & Logic"; sophomores continued the languages and added rhetoric, geometry, and geography; juniors, still working with the languages, studied natural philosophy, astronomy, and advanced mathe-

matics; and the seniors read metaphysics and ethics. All classes spent their Saturdays on divinity, their Fridays in Latin, Greek, or Hebrew declamations; and the seniors devoted some time to disputations.[15]

The Yale scheme, it will be observed, was a modification of the Harvard plan, distinguished chiefly by the way it pushed down geometry (and, presumably, any necessary arithmetic) into the sophomore year, leaving the junior year free for more advanced mathematics, astronomy, and natural philosophy or physics. This was the characteristic plan in the latter half of the eighteenth century. It may be seen in Princeton programs dating from 1764, 1794, and 1802; in Brown curricula of 1783 and 1803; in the 1795 laws of the University of North Carolina; and in the Dartmouth schemes of 1796 and 1801.[16] All followed the same basic pattern: no scientific subjects whatever for the freshmen; a little geography and elementary mathematics for the sophomores (although Brown postponed arithmetic and geometry until the junior year); advanced mathematics and natural philosophy for the juniors; and a general review for the seniors. At Dartmouth, chemistry and natural history were introduced in the final year, and, as will appear, there were some similar variations elsewhere.

The remarkable uniformity of the curriculum at six of the colleges between 1740 and 1800 is in contrast with the programs at three of the major institutions: Pennsylvania, Columbia, and William and Mary. Developments at each of these deserve careful description.

At Pennsylvania it is again possible to use the statistical method of estimating the proportion of time allotted to the various subjects. Provost Smith's plan called for three years of three terms each, the summer and fall terms being three months long, the winter term four months. Each student attended three

classes daily. Variations in the schedule were allowed to give room for disputations, declamations, and composition, and there was some overlapping. But it is not misrepresenting the scheme very much to assign three "hours" of credit for each class in the three-month terms, four "hours" for each class running four months. By such computation the student at Pennsylvania may be said to have accumulated ninety hours, which were distributed as follows:[17]

Latin and Greek	29	hours
Mathematics	22	
Ethics and Politics	10	
Natural Philosophy	7	
Logic	4	
Declamations, etc.	4	
Review	4	
Chemistry and Agriculture	4	
Astronomy and Natural History	3	
History	3	

Under Smith's program, approximately forty per cent of the classroom time was devoted to scientific subjects, among them chemistry, agriculture, and natural history. The ancient languages were still the core of the program, but logic and rhetoric had lost their central positions. Probably neither Pennsylvania nor any other college actually gave forty per cent of the student's time to the sciences, but we may be fairly sure that if nine per cent was a rough approximation of the stress on the sciences in 1640, twenty or twenty-five per cent is not far wrong as an estimate of the stress a hundred years later.

Provost Smith's curriculum has long been regarded as the first and most significant expression of a new utilitarian tendency in American higher education.[18] It was followed, in its essentials, at Washington College in Maryland, where Smith was president in 1782–89.[19]

The same tendency, however, is apparent, although not so consistently, at Columbia. President Samuel Johnson, advertising the opening of the college in which he was for a year the sole teacher, devoted a paragraph to asserting the primacy of religion, virtue, and good citizenship among the aims of higher education, but he did not stop there. Having first provided for a serious and industrious course of life, the college planners desired, he continued,

> to instruct and perfect the Youth in the Learned Languages, and in the Arts of *reasoning* exactly, of *writing* correctly, and *speaking* eloquently; and in the Arts of *numbering* and *measuring;* of *Surveying* and *Navigation*, of *Geography* and *History*, of *Husbandry*, *Commerce* and *Government*, and in the Knowledge of *all Nature* in the *Heavens* above us, and in the *Air*, *Water* and *Earth* around us, and the various kinds of *Meteors*, *Stones*, *Mines* and *Minerals*, *Plants* and *Animals*, and of every Thing *useful* for the Comfort, the Convenience and Elegance of Life; in the chief *Manufactures* relating to any of these Things: And, finally, to lead them from the Study of Nature to the Knowledge of themselves, and of the God of Nature, and their Duty to him, themselves, and one another, and every Thing that can contribute to their true Happiness, both here and hereafter.[20]

The early history of the college which grew out of such all-embracing ambitions as these is very curious. On paper, no other American institution of learning appeared as anxious as was Columbia to adjust itself to utilitarian needs. The first laws, adopted in 1755, state that

> The business of the second and third years shall be after a small system of Logic to study the Mathematics, and the Mathematical and Experimental Philosophy in all the severall branches of it, with Agriculture and Merchandize together with something of the Classics and Criticism all the while.[21]

Between what was projected and what was actually taught there was, however, a wide discrepancy. When the instruction began Johnson confined himself to Greek, logic, metaphysics, and ethics.[22] Later Columbia specialized in founding professorships in particular fields—before 1800 twenty-six differently described departments of knowledge appear in the records. The list is thought-provoking:[23]

Mathematics and Natural History.....1757–1820
Moral Philosophy 1762–1857
Mathematics 1765–
Natural Philosophy 1765–1776, 1785–1786
Anatomy 1767–1813, 1860–
Pathology and Physiology 1767–1776
Surgery 1767–1813, 1860–
Theory and Practice of Medicine 1767–1776, 1795–1808
Chemistry and Materia Medica 1767–1776
Midwifery 1767–1813, 1860–1875
Natural Law 1773–1776
The French Language 1784–1799, 1828–1866
The Greek and Latin Languages.....1784–1857
Rhetoric and Logic 1784–1787
The Oriental Languages 1784–1787, 1792–1799
The German Language 1785–1794, 1830–1890
Geography 1784–1799, 1902–
Chemistry 1784–
Natural History 1785–1786
Institutes of Medicine 1785–1813
Practice of Medicine 1785–1813, 1892–
Natural History, Chemistry, Agriculture, and the other arts depending thereon..1792–1802
Materia Medica 1792–1813, 1860–
Botany 1792–1811, 1860–
Law 1793–1798, 1823–
Rhetoric and Belles-Lettres 1795–1799

It should be noted that eight of these twenty-six professorships were in the sciences, eight more in some branch of medicine.

In several instances, they were the first of their kind to be established in any American college.

Nevertheless, Columbia in 1801 appears to have flattered itself chiefly upon offering the most careful instruction in the Greek and Latin languages in the country.[24] Its teaching will be observed more closely a little later; more to the point here is the curriculum at the end of the century, of which Samuel Miller has given an unusually specific description. There is little that is exceptional about it.

First Year

Sallust, Livy, two books of Virgil's Georgics, part of the New Testament in Greek, from 20 to 30 dialogues of Lucian, and two books (generally) of Xenophon. To these are added, Arithmetic, Algebra, a small portion of Euclid, and Latin Composition.

Second Year

finish Virgil's Georgics, Horace's odes, and part of his Satires, the Orations of Demosthenes, an additional portion of Xenophon, and two books of Homer. With these are mingled English Grammar, six books of Euclid, Modern Geography, Trigonometry, with its various applications to Surveying, Navigation, &c., Latin and English Composition.

Third Year

Horace's Epistles and Art of Poetry, six books of Homer, Conic Sections, Speric [*sic*] Trigonometry, with its application to Astronomical problems, ancient Geography, rhetoric, and English composition.

Fourth Year

Natural Philosophy, Logic, and Moral Philosophy, Terence, Longinus, Chemistry, and English Composition

Public speaking once a week throughout the course.[25]

In comparison with the pattern prevalent in most of the other colleges, this program is generous in the space given to mathematics and geography, but it retains little of the sweeping utili-

tarianism which was evidently in the minds of the founders, and which reappeared later in such Columbia ventures as its pioneer school of mining and its present-day leadership in agricultural history.

A word, finally, about the extraordinary events at William and Mary in 1779. The procedure there, as has been seen, was to set up degree requirements and then abandon all machinery except, presumably, a system of advice for ambitious students and some kind of final examination. The degree requirement, as stated in the laws published in 1792, was as follows:

> For the degree of Batchelor of Arts, the Student must be acquainted with those branches of the Mathematics, both theoretical and practical, which are usually taught as far as Conic Sections, inclusive, viz. The first six books of Euclid, plain Trigonometry, the taking of Heights and Distances, Surveying, Algebra, the 11th and 12th books of Euclid, Spherics, Conic Sections: must have acquired a knowledge of Natural Philosophy as far as it relates to the general principles of Matter, Mechanics, Electricity, Pneumatics, Hydrostatics, Optics, and the first principles of Astronomy; must be well acquainted with Logic, the Belles Letters, Rhetoric, Natural Law, Laws of Nations, and the general principles of Politics; he must also have a competent knowledge of Geography, and of Ancient and Modern Languages.[26]

Scientific subjects loom large in this curriculum and, elementary as most of them would seem to the graduate of a first-rate technical high school today, they must have loomed large to the undergraduate at William and Mary. If he seriously attempted to prepare for examination in these subjects, he was a world away from his predecessors under Dunster at Harvard, getting ready to display their mastery of Latin and logic in syllogistic disputations at commencement.

To judge by the prevailing curriculum, the sciences had already made a large place for themselves in the American

colleges by the end of the eighteenth century. It is evident that adjustment to a new emphasis began between 1690 and 1740, and was general thereafter.

What the curriculum cannot tell us is the nature and the depth of the disciplines to which it gave recognition. A course of studies, as all college teachers know to their sorrow, does not make a mind. Some consideration of the teaching and the textbooks of the seventeenth and eighteenth centuries is therefore next in order.

V

Teachers, Methods, and Textbooks

Of the three chief methods of teaching—recitation, lecturing, and laboratory or field work—the last was all but unheard of before 1800. Leonard Hoar, president of Harvard in 1672–75, was well over a century ahead of his time when he informed Robert Boyle that the plans for the college included

> A large well-sheltered garden and orchard for students addicted to planting; an ergasterium for mechanick fancies; and a laboratory chemical for those philosophers, that by their senses would culture their understandings, . . . for readings or notions only are but husky provender.[1]

Botanical gardens, engineering shops, chemical, physical, and biological laboratories—all are, so far as the colleges go, the contributions of the nineteenth century.

What, then, was the nature of the teaching of the sciences? With little exception, it consisted either of daily recitation from textbooks or of lecturing with the help of whatever apparatus the college could afford. A few students botanized a little or collected cabinets of minerals and birds' eggs, or observed the stars and planets through a college telescope, or wandered beyond the college yards to do a little surveying or measuring of the height of the local church-steeple. Such adventures were rare, however, and came chiefly to those students who

were blessed with enthusiastic teachers. In some cases it is possible to discover who those teachers were and what they did.

For the routine work the colleges depended almost entirely upon the tutorial system. Throughout the seventeenth century the Harvard staff consisted of the president and two or three young men, usually recent graduates staying on in Cambridge to read divinity until they were called to a church. Their titles varied, but elsewhere than at Harvard they were usually called tutors rather than fellows. They were paid practically nothing, at which they were sometimes known to complain. Until 1767 a Harvard tutor was normally assigned to a class rather than to a subject, that is, he supervised all the studies of freshmen or sophomores or juniors or seniors.[2] Sometimes he handled two classes, and taught everything in the curriculum except what the president retained for himself.

Under such circumstances the work was inevitably uneven, consisting usually of mulling through a textbook and adding what commentary the tutor could command. Serious students kept notebooks in which they systematized their knowledge or copied passages from related books in the college library. Frequently an industrious tutor compiled a manuscript textbook and used it with his pupils. Some of these materials survive, although there are not as many of them as could be wished for. Together with the printed books which contain names and notes and other evidence of student use, they provide a good deal of information on the nature of the early teaching. Still another key is offered in the printed commencement theses from Harvard, Yale, and Brown—lengthy series of propositions in Latin which the graduating seniors were ready to defend, displaying their mastery of the language and the syllogism to their admiring friends. It was customary, fortunately, to indicate those theses chosen in advance for public discussion.

Lecturing was not uncommon in the seventeenth century; the president was expected to talk once in a while. Later, with the appointment of professors in specialized fields, the lecturing method was gradually integrated with the basic tutorial scheme, successfully, it would appear, at Harvard, Princeton, and William and Mary, rather less so elsewhere. In the period of established pattern, lecturing became a common procedure in such fields as physics and chemistry, where demonstration methods were obviously superior to mere reading and recitation. Some notion of the content of a few of the lecture courses may be obtained from printed outlines and student notes, as well as from the records of the acquisition of apparatus, for which many institutions expended, considering the slenderness of their resources, amazingly large sums of money.

THE FORMATIVE PERIOD

The first stage of instruction has been fully and ingeniously described by Samuel Eliot Morison in his *Harvard College in the Seventeenth Century*. The scientific subjects which have histories in that era are mathematics, astronomy, and physics. As has already been said, mathematics and astronomy were recited by the seniors, physics or natural philosophy (which was actually an introduction to all the sciences) by the three upper classes, but primarily, probably, by the juniors. The physics course contained most of what Harvard students encountered in the fields we now call chemistry, meteorology, physiology, and botany, as well as some rather outmoded physics. Botany, although it appeared as a separate subject in Dunster's program of 1642, does not seem to have long survived apart from physics.[3]

It is well to begin with mathematics. "Theses Arithmeticae" and "Theses Geometricae" appear in the Commencement pro-

gram for 1653; thereafter they are combined with some astronomical propositions as "Theses Mathematicae." In 1693 an astronomical thesis, "Corpora Cælestia sunt Corruptibilia," was designated for public discussion, the only one of the class so singled out before 1700.[4] The elementary nature of the mathematical propositions, and the absence of any surviving textbooks, make it unlikely that the mathematical instruction was of much importance. President Dunster, however, is known to have compiled a manuscript system of geometry from a 1639 edition of one of Petrus Ramus's textbooks, and we are told that in 1652 one Harvard student spent his summer assisting in a none too accurate survey of the northern boundary of Massachusetts. There is no hint, however, that anyone expected Harvard in its formative period to provide training in such workaday subjects as surveying and navigation.

Judging by the commencement theses alone, one might think that astronomy was even more lightly regarded. However, as the thesis of 1693 already quoted faintly suggests, Harvard was teaching the New Astronomy of Copernicus, Galileo, and Kepler at a fairly early date. The evidence lies largely in a long series of almanacs, published under the direction of the college at the Cambridge press. The task of preparing them was usually turned over to a tutor or a candidate for the M.A. degree, who had, below and after his tables of calculations, some blank spaces to be filled with verses or brief essays which might be instructive to the buying public. Some young men naturally preferred to make verses, but Zechariah Brigden, compiling the almanac for 1659, chose to give his readers an account of the Copernican system which has been called "the earliest extant scientific essay by a Harvard graduate."[5] Samuel Cheever's almanac for 1661 contained a description of the rise and progress of astronomy; later compilers attacked Ptolemaic

concepts or offered accounts of comets; all in all, there is enough to justify speaking of a Harvard "school" of astronomy after 1660.[6] It was composed of tutors rather than of undergraduates, but it made astronomy "the only subject in which the College made some contribution toward the advancement of learning" in this period.[7] In 1672, Harvard star-gazers were delighted by the arrival of a telescope, the gift of John Winthrop, Jr., the Connecticut leader who was a charter member of the Royal Society of London. Eight years later this instrument was used for observations of the Great Comet of 1680 by Thomas Brattle (1658–1713*).[8] His results, transmitted to John Flamsteed, the Royal Astronomer at Greenwich, were communicated to Newton, who mentioned them respectfully in the *Principia.* Brattle and others used the telescope frequently thereafter to observe eclipses and other phenomena.

The basic scientific subject, however, was physics. From its small place on Dunster's program—occupying one period each week for a single quarter—it had come to be required in part of each of the last three years. Both printed and manuscript textbooks are known to have been used, and there is a perceptible shift from Aristotelian ideas and methods toward the New Science of Descartes, Boyle, and Newton.[9]

The most popular Aristotelian textbook was Johannes Magirus's *Physiologiae Peripateticae,* first published in 1597. Six copies of five different editions, each with the name of one or more Harvard or Yale students somewhere upon it, are extant. Magirus, a professor at Marburg, had compiled and arranged the remarks of Aristotle and his commentators on the four elements, the different classes of bodies, the phenomena of generation and corruption, and other traditional topics. After studying this or a similar work, Harvard seniors were

presumably ready to defend such propositions as "Mundus est in loco" (1653), "Non datur transmutatio elementorum" (1670), and "Anima rationalis creatur" (1670).

THE TRANSITION PERIOD

About 1670, perhaps because of some infiltration of Cartesian ideas, there was a revolt at Harvard: the class of 1671 refused to read Magirus.[10] Their objection was the first breath of the transition in scientific studies. During the next few college generations students at Harvard used textbooks which attempted to reconcile the theories of Descartes or the Bible with the dicta of Aristotle. Then, in 1687, Charles Morton's *Compendium Physicae,* a manuscript textbook, was adopted, to remain in use for most of the next forty years. It has recently been printed from one of the thirteen extant transcriptions which were made by Harvard students.[11]

Morton had come to Massachusetts in 1686, expecting to be made president of Harvard. Behind him lay years of teaching in one of the most famous academies of the English Dissenters, where he had collected scientific apparatus and kept himself informed about the discoveries of Boyle, Newton, and other members of the Royal Society. For the use of his students, he had prepared systematic manuals in English, of which the *Compendium Physicae* was one. Although arranged according to the old Aristotelian distinctions, it contained much new information and described many of the experimental methods which were enlivening European science.

The transition period at Harvard and elsewhere extends from the introduction of Morton's book until about 1740, when John Winthrop was beginning his forty-year term as Hollis professor, and Thomas Clap, as rector at Yale, was giving his particular attention to the scientific subjects there. Before returning to

events at Harvard, it is appropriate to see what happened at the other colleges.

Nothing is known about the instruction offered by the ill-fated Le Fevre at William and Mary in 1711–12. Nor is there much information concerning his successor, the Rev. Hugh Jones, who held the post from 1717 to 1729 (although he was probably not an active teacher after 1722). Jones asserted in *The Present State of Virginia* (London, 1724) that Virginians generally desired only necessary learning and wanted to get that by the "shortest and best" methods. Submitting to the judgment of the plantation gentlemen, he composed for his classes a number of short treatises, among them

> an *Accidence to the Mathematicks*, especially to *Arithmetick* in all its Parts and Applications, *Algebra*, *Geometry*, *Surveying of Land*, and *Navigation*.[12]

If Jones was actually teaching algebra at William and Mary between 1717 and 1722, he was among the first to introduce that subject into the college curriculum in America. His manuscript textbook has not survived, although the British Museum has a later mathematical paper, dealing with calendars and the advantages of eight over ten as the fundamental number for a universal system of numeration, weights, and measures.[13] Jones was evidently a man with a mind of his own.

That Jones was right in gauging the Virginians as utilitarian is suggested by the interests of his two successors, Alexander Irvine, who held the professorship in 1729–32, and Joshua Fry (1700?–54*), the incumbent in 1732–37.[14] Although there is no means of knowing what they taught, Irvine was known locally as an excellent surveyor, and Fry, a few years later, collaborated with Thomas Jefferson's father in surveys result-

ing in *A Map of Virginia,* one of the most famous of colonial maps.

At Yale, the sciences got off to a bad start under the Rev. Abraham Pierson, the first rector. A graduate of Harvard in 1668, Pierson used as his textbooks in natural philosophy the Magirus work, discarded at Harvard soon after he left, and a manuscript system which he had compiled as an undergraduate.[15] Based upon an English manual printed in 1657, Pierson's manuscript physics was vastly inferior to Charles Morton's as an introduction to current scientific thought.

Some improvement was effected by the use of Jean Le Clerc's *Physica* in the days of Rector Cutler (1719–22), and of Jacques Rohault's under Rector Williams (1726–39),[16] although it is debatable whether either was superior to Morton's *Compendium Physicae.* Rohault's textbook had been published first in 1671, to disseminate Cartesian principles. Immediately translated into Latin, it was "Englished" by Samuel Clarke in 1710; he added notes in correction of points inconsistent with Newtonian theories. Clarke's Rohault was long standard in the English universities, although scorned by the more thoroughgoing Newtonians.[17] Le Clerc, a Swiss scholar long resident in Holland, was actually a belated Scholastic, well known in his time for his logical summaries of all branches of knowledge.[18]

The course of events at Yale may be followed in the experience of Samuel Johnson of the class of 1714, who was later the first president of King's College. The synopsis of philosophy which he compiled as an undergraduate has recently been printed,[19] and is ample verification of his own statement that his education in college consisted of "the scholastic cobwebs of a few little English and Dutch systems." Johnson, however, was suddenly introduced to a new world of ideas by the arrival in 1714 of the shipment of more than seven hundred volumes

known as the Dummer gift.[20] Among the writers who were persuaded by Jeremiah Dummer, Connecticut's colonial agent in London, to give some of their own works to the college, were Isaac Newton, Edmund Halley, William Whiston, and John Woodward, the leading figures in the Royal Society. The copy of the *Principia,* in its second edition, donated by Newton, is among the first of which there is record on this side of the Atlantic.[21]

The effect of the Dummer books was tremendous. One may attribute to them the conversion of Johnson, Rector Cutler, and five of their associates to the Anglican Church, a development which spread consternation among the trustees of staunchly Congregational Yale. That question aside, however, there were noteworthy results. Finding that he could not understand the mathematics of the *Principia,* Johnson, who was a tutor between 1716 and 1719, undertook to revise the instruction in that field. That he introduced algebra, probably for the first time in an American college, appears from the Yale commencement theses of 1718.[22] Eight of the thirty mathematical propositions on that list were algebraic, and, although they were such elementary statements as "The fundamental parts of algebra are numeration and equation," a beginning had been made. Miss Lao G. Simons, the chief authority on the history of algebra in America, points out that the 1718 theses reach, in their most difficult proposition ("The surface of a sphere is four times the area of its greatest circle"), the level of knowledge of the present-day college freshman. That level was high for the time, and probably was not maintained at Yale after Johnson's departure, for there is no further evidence of unusual concern with either mathematics or natural philosophy until the appointment of Thomas Clap as rector in 1739. His training had been received at Harvard, where he was graduated in 1722.

The mathematical and astronomical tradition at Harvard, begun chiefly, as has been seen, by Thomas Brattle, was maintained early in the eighteenth century by Thomas Robie of the class of 1708, who was a tutor for most of the time between 1712 and 1723.[23] An active investigator in astronomy and meteorology, Robie compiled eleven almanaces, while ten of his observations found a place in the *Philosophical Transactions.* He was elected a Fellow of the Royal Society in 1725.

Such a man ought not to have been satisfied with teaching Morton's manuscript physics and the mere fundamentals of arithmetic and geometry. There is no evidence, however, that he was dissatisfied, and one can only guess that he may have had something to do with the appearance of fluxions, or the Newtonian calculus, on the Commencement program for 1719, and of six theses on algebra in the list for 1721.[24] Such guessing is not supported by the student notebooks which have survived. There are extant transcriptions of Morton's textbooks by members of the classes of 1714, 1717, 1719, and 1725, while the mathematical notebook of a graduate of 1721 contains only material in arithmetic and the first five books of Euclid.[25] Nevertheless, it is hard to give up the conviction that Robie must have been a force in the training of both Isaac Greenwood and Thomas Clap. It is known, indeed, that Greenwood carried with him a letter from Robie when he went to pursue his studies in London.

Greenwood concludes the transition stage and begins the final triumph of Newtonianism. His tragic life should not be allowed to obscure his revolutionary influence upon science at Harvard. He found the instruction almost wholly book learning; he left it marked by awareness of the prime importance of observation and experiment. He recognized the necessity of better mathematical foundations, and he provided textbooks to

meet that need. He gave American students their first sight of the demonstration of physical principles by laboratory apparatus, of the planetarium as a means of visual apprehension of the facts of astronomy. There is no better example of the swift transmission of teaching method from London lecture halls to an American college.

As a student in London in 1724–26, Greenwood attended the lectures of J. T. Desaguliers and, probably, William Whiston and Francis Hauksbee, all well-known teachers of Newtonian science. Back in Boston, and before his election as Hollis professor, Greenwood issued a six-page prospectus for a course of sixteen lectures modeled upon those which he had seen and heard abroad. The title, although long, is so self-explanatory that it is well to quote it: *An Experimental Course of Mechanical Philosophy, Whereby Such a Competent Skill in Natural Knowledge May Be Attained to, (by Means of Various Instruments, and Machines, with Which There Are above Three Hundred Curious, and Useful Experiments Performed) That Such Persons as Are Desirous Thereof, May, in a Few Weeks Time, Make Themselves Better Acquainted with the Principles of Nature, and the Wonderful Discoveries of the Incomparable Sir Isaac Newton, than by a Years Application to Books and Schemes.*

Manuscript annotations on a copy of this prospectus at the Massachusetts Historical Society show that the course was given between January and April, 1727, although not exactly as announced. By comparing its outline with the published lectures of Greenwood's London teachers, it is possible to reconstruct, in general, what Greenwood had to say, and to identify the types of apparatus which he must have employed. His chief topics were mechanics, acoustics, electricity, magnetism, and, finally, the application of the theory of gravity to the

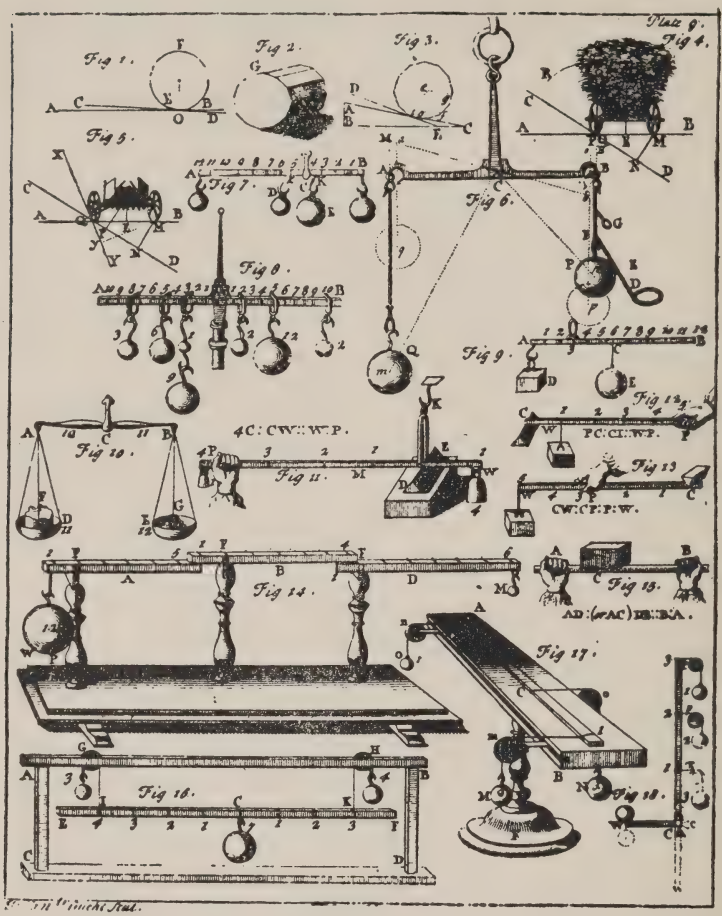


Plate illustrating balances of different sorts, from J. T. Desaguliers' *Course of Experimental Philosophy*

celestial bodies. He was apparently provided with loadstones, an air-pump, glass rods and planes, mercury, balances and the various types of levers, pulleys, a monochord, terrestrial and celestial globes, some kind of orrery or "copernicus," and perhaps with other machines. His course was probably the first of its kind in the colonies. Two weeks after its completion he was elected Hollis professor.

His duties at Harvard were laid down specifically in the minutes relating to the gift of funds. The Hollis professor was to

> Instruct the Students in a System of Natural Philosophy & a course of Experimental in which to be comprehended, Pneumaticks, Hydrostaticks, Mechanicks, Staticks, Opticks, &c in the Elements of Geometry to-gether with the doctrine of Proportions the Principles of Algrebra [*sic*] Conic Sections, plain & Sperical Trigonometry with the general principles of Mensuration, Plain & Solids, in the Principles of Astronomy & Geography, viz. the Doctrine of the Spheres the use of the Globes, the motions of the Heavenly Bodies according to the different Hypotheses of Ptolomy [*sic*] Tycho Brahe & Copernicus with the general Principles of Dialling the Division of the World into its various Kingdoms with the use of the Maps, &c.[26]

Once each year Greenwood went through such a course as he had given to private subscribers, with the aid of magnificent apparatus provided by Thomas Hollis. But what was, in the long run, more important, was his work in improving the quality of Harvard mathematics, to meet the same need that had been observed a few years earlier by Samuel Johnson at Yale. In 1729 he published his *Arithmetick Vulgar and Decimal,* which historians of mathematics have pronounced modern in spirit and notation.[27] For his algebra classes he prepared a manuscript textbook which shows genuine enthusiasm for the subject and fairly wide reading it its literature.[28]

In all probability he was the first American to instruct private students in the Newtonian calculus.[29]

Greenwood was also active as a teacher of astronomy, and in 1734 issued a prospectus for a summer series of lectures in which he promised to show his customers, if possible, sun-spots, the mountains of the moon, eclipses of the satellites of Jupiter, and some of the nebulae.[30] The telescope was probably one belonging to the college.

When Greenwood was discharged in 1738, he left behind him at Harvard a new way of doing things, and students who were ready to take up, with more sobriety, where he left off. For the rest of the century philosophical apparatus and a course of demonstrations were among the chief ambitions of every college in the country.

THE PERIOD OF ESTABLISHED PATTERN

By 1740, it is safe to say, the mathematical sciences had established themselves firmly. Mathematics was thereafter deemed desirable not merely for its practical utility in surveying and navigation but also as an essential aid in the mastery of Newtonian physics and astronomy. Natural philosophy, although still far from what would now be called an experimental science, had become a subject which was to be taught by observation and demonstration as well as by books.

The final period of the teaching of science before 1800 is notable for the general uniformity with which the new emphasis was fitted into the curriculum. Also observable, however, is the emergence of a few separate disciplines from the all-inclusive field of natural philosophy or physics. Of these new subjects chemistry, geography, and natural history are the most important. Astronomy can scarcely be separated from physics.

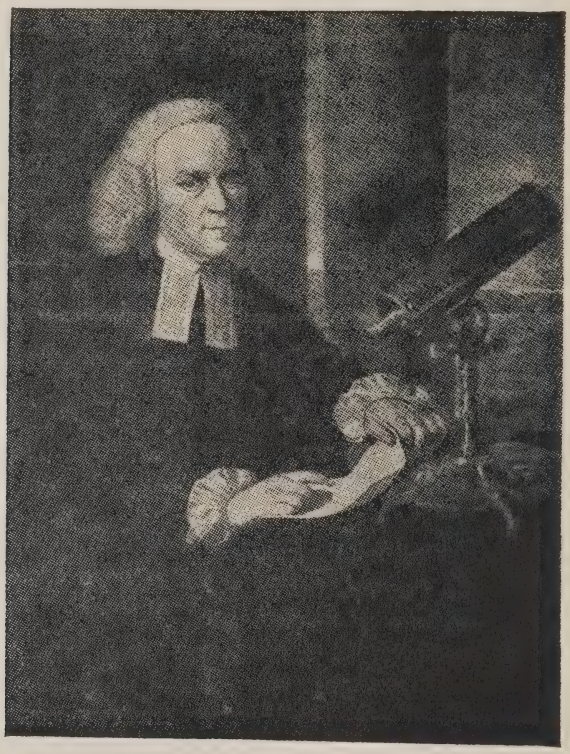
Since the entire period was dominated by a vast veneration for the mathematical genius of Sir Isaac Newton, it is fitting to begin with what happened in mathematics.

MATHEMATICS

John Winthrop, a member of the Harvard class of 1732, was only twenty-four years old when he was chosen Hollis professor in 1738; he held that chair until his death in 1779—a period of forty-one years.[31] Thomas Clap, about ten years older than Winthrop, was elected rector of Yale in 1739 (after 1745 his title was that of president) and resigned in 1766.[32] Both men seem to have required a few years of preparation to give their students mastery of Newtonian mathematics. The evidence is a gradual change in the nature of the commencement theses at Harvard and Yale. In the forties, the most prominent class of topics was conic sections. Beginning in 1751, fluxions became the most conspicuous topics at Harvard, and remained so until the end of the century; they appeared first at Yale in 1758 and gradually became more difficult.[33] When Clap resigned, he expressed pride that some of the better students at Yale had mastered all the usual branches of mathematics, including fluxions.

The standard college textbook in mathematics for the larger part of the eighteenth century was John Ward's *Young Mathematician's Guide,* an English compilation first published in 1707 and in its seventh edition by 1740.[34] It had sections on arithmetic, algebra, geometry, conic sections, and the "arithmetic of infinites," with an appendix on practical gauging. Harvard was using it for some time before the appointment of Winthrop, and may still have been using it in 1794; it was not displaced at Yale until Nicholas Pike's *Arithmetic* was adopted in 1788; it was one of the books which Provost Smith

recommended for supplementary reading at Pennsylvania; and it is also thought to have been in use at Brown and Dartmouth. Ward was ordinarily supplemented with an edition of Euclid and with such works as Nathaniel Hammond's *Elements of Algebra* (London, 1742).[85]



JOHN WINTHROP (1714–1779)
Hollis Professor of Mathematics and Natural Philosophy, Harvard College, 1738–1779

Winthrop was unquestionably the most competent teacher of mathematics in his generation. He acquired a copy of the third edition (1726) of the *Principia* in 1739 and in the course of time accumulated a considerable working library in mathematics, including works by Barrow, Descartes, and Oughtred, and four different editions of Euclid.[36] That he was careful to explain the relation of mathematics to the physical sciences is suggested by one of the eulogistic comments after his death. Too many professors, remarked a "Gentleman of Eminence in an adjacent State,"

> content themselves with familiarizing the discoveries of *Newton* to the capacities of children, petit maitres and ladies; and those who have but a superficial acquaintance with the elements of mathematics. An elegant and entertaining course of *experimental philosophy* now takes the place of those deep and great ratiocinia on the laws of nature.[37]

The implication is that Professor Winthrop was never guilty of popularizing. "I believe," wrote Ezra Stiles, "he had not his equal in Europe: he was a perfect master of Newton's Principia—which cannot be said of many Professors of Philosophy in Europe."[38]

Neither Yale nor Harvard maintained its mathematical prestige throughout the century. Yale sought to compensate for the loss of Clap by establishing a professorship of mathematics and natural philosophy in 1770, but it had no endowment, and neither of the incumbents—Nehemiah Strong (1770–81) and Josiah Meigs (1794–1801)—was either happy in the post or notably proficient.[39] Like President Stiles, they were more interested in astronomy than in mathematics. The same thing may be said of Samuel Williams, who succeeded Winthrop at Harvard, although there remains, in the college archives, a manuscript lecture by Williams on the certainty,

usefulness, and ease of mathematical science.[40] Samuel Webber, Hollis professor from 1789 until 1804, when he became president, published in 1801 a two-volume *System of Mathematics* which was widely used as a textbook in the New England colleges and went into a second edition.[41] Webber does not appear, however, to have had an especially wide reputation in his field.

The other colleges may be divided into two classes: those which were able to find outstanding mathematical talent for their staffs, and those which were not. The higher branches evidently demanded more training and experience than the mine run of tutors could provide. Among the also-rans must be ranked, in the absence of fuller information, Dartmouth, William and Mary, and perhaps Brown. At Columbia, Pennsylvania, and Princeton, on the other hand, mathematics at the end of the century was probably in better state than it was at Harvard.

Dartmouth established a professorship of mathematics and natural philosophy in 1782, but the holder of the chair until 1804 was Bezaleel Woodward, who, although a highly useful teacher and a shrewd business manager, was hardly an expert in the higher mathematics.[42] He was using as his textbooks in 1792 Pike's *Arithmetic,* Ward's *Mathematics,* and Hammond's *Algebra.*[43]

Fluxions do not appear among the B.A. requirements at William and Mary in 1792, and although Samuel Miller gave a considerable list of the textbooks in natural philosophy in 1803 he provided no information on mathematics. Thomas Jefferson, to be sure, once remarked that when he was young mathematics was the "passion" of his life, but there is little evidence of a strong mathematical tradition at Williamsburg.[44]

At Brown fluxions were probably studied in 1769, soon after the founding of the college.[45] David Howell (1747–1824*), first tutor and first professor (of natural philosophy) may have been responsible, although he came in time to be much more concerned with politics than with the teaching of science.[46] Benjamin West (1730–1813*), who was appointed professor of mathematics and astronomy in 1786 and actually lectured from 1788 to 1799, was a talented amateur, known chiefly as an almanac-maker and astronomer. Asa Messer (1769–1836*), identified with Brown for almost his entire life, as tutor (1791–96), librarian (1792–99), professor of learned languages (1796–99), professor of mathematics and natural philosophy (1799–1804), president *pro tempore* (1802–4), and president (1804–26), was an inventor with a "taste" for mathematics, natural philosophy, and mechanics, but he was scarcely a distinguished specialist.[47] The mathematics textbooks used at Brown in 1771 included John Hill's *Arithmetic* (1716; 11th ed., London, 1772) and Hammond's *Algebra.* In 1783 the junior class was still using Hammond, together with Daniel Fenning's *Arithmetic* (perhaps *The Schoolmaster's Most Useful Companion,* London, 1765, or *The Ready Reckoner,* London, 1757, and in its 6th ed., Boston, 1742), Edmund Stone's edition of Euclid (London, 1731 or 1762), Benjamin Martin's *Trigonometry* (1735?), John Love's *Surveying* (London, 1688; 8th ed., 1768), and William Wilson's *Navigation* (London, 1773).[48]

One might expect Samuel Johnson, at King's, to favor mathematics after his experience at Yale. It is perhaps noteworthy that his first professorial appointment went to one of Winthrop's bright young men, Daniel Treadwell, who became professor of mathematics and natural history in 1757.[49] Treadwell unfortunately died of consumption three years after his induction. Of his successors—Robert Harpur (1762–67),

Myles Cooper (1767–75), and John Kemp (1786–1812)—only the last-named was outstanding. Born in Scotland, Kemp (1763–1812*) won a mathematical prize at Aberdeen University when he was nineteen, and the next year was in Virginia, presiding over an academy. He went to Columbia in 1785 on a one-year trial; it is said that he proved himself at the end of the year by a public examination of his class, at which each student drew a number and, with nothing more to go on, demonstrated the theorem of Euclid to which that number corresponded. At twenty-three, with this evidence of his success as a teacher, he became professor of mathematics and natural philosophy, and in 1795 was made professor of geography as well. Kemp seems to have been a conscientious teacher, but there is some question about his emphasis on the higher branches; fluxions, for example, do not appear on the curriculum reported by Miller in 1803. On the other hand, it is known that Kemp was unusually anxious to display the utilitarian value of his work. He is best remembered as the teacher who impressed De Witt Clinton with the importance of canals; one of Clinton's biographers says that Kemp

> was in the habit, in his mathematical course, of enforcing the yet unpublished views of his master [Professor Hamilton of Aberdeen] on the subject of public debts; and urging the necessity of providing for every debt contracted a sum sufficient not only to defray the interest, but to pay off the principal by an annuity. In his lectures in illustration of the mechanical part of natural philosophy, he prided himself on giving every subject a practical bearing, and thus the principles and history of canal navigation formed a favourite theme.[50]

Kemp's Scotch ideas of public finance may account in part for his eventual break with Clinton; as a Federalist he was perhaps unable to keep his politics entirely separate from his mathematics.

Under Provost Smith in 1756 Pennsylvania (then the College of Philadelphia) inaugurated a remarkably full program of arithmetic, algebra, geometry, trigonometry, surveying, navigation, conic sections, and fluxions, with Stone's Euclid and John Wilson's *Trigonometry* (Edinburgh, 1714) named as textbooks.[51] Smith, moreover, had somewhere acquired impressive familiarity with mathematical literature. A list of his suggestions for supplementary reading in this field will show that his acquaintance with the work of recent mathematical writers, many of them Scotch, was out of the ordinary:

Barrow's Lectures. (Isaac Barrow, *Lectiones Geometricae*, London, 1670; English trans. by Edmund Stone, London, 1735.)

Pardie's Geometry. (Ignace Gaston Pardies, *Elemens de geometrie*, 4th ed., Paris, 1683; English trans. by J. Harris, London, 1701, and 8th ed. by 1746.)

Maclaurin's Algebra. (Colin Maclaurin, *Treatise of Algebra*, London, 1748.)

Ward's Mathematics.

Keil's Trigonometry. (John Keill, *The Elements of Plain and Spherical Trigonometry*, 3d ed., Dublin, 1726.)

Patoun's Navigation. (Archibald Patoun, *A Treatise of Practical Navigation*, London, 1751.)

Gregory's Geometry. (David Gregory, *Treatise of Practical Geometry*, Edinburgh, 1745, 1751; trans. from earlier Latin eds.)

Simpson's Conic Sections. (Identification uncertain.)

Maclaurin's and Emerson's Fluxions. (Colin Maclaurin, *A Complete System of Fluxions*, 2 vols., Edinburgh, 1742; William Emerson, *The Doctrine of Fluxions, with Their Application and Use in the Several Points of Mathematics and Natural Philosophy*, London, 1743, 1748, 1757.)

The first teacher at Pennsylvania was presumably Theophilus Grew (d. 1759*), who had been mathematical professor at the Philadelphia academy since 1750 and was renowned through-

out the middle colonies as a private tutor and consultant in difficult surveying problems.[52] Despite the vicissitudes of administration, Pennsylvania maintained a strong mathematical tradition throughout the century, most notably under Robert Patterson (1743–1824*), professor of mathematics from 1779 until 1814. Student notebooks of the eighties and nineties testify to the fact that he occasionally touched upon fluxions, although there is some question of the quality of his work.[53]

Princeton climbed upon the professorial bandwagon in 1764, with four appointments, one of them in mathematics and natural philosophy.[54] The chair was not actually filled, however, until 1771, when William Churchill Houston (1746–88*) was appointed. Although not an outstanding mathematician, Houston taught fluxions if one can trust existing journals and letters.[55] In 1787, after a two-year *ad interim* appointment, Princeton called to this chair another distinguished Scot, Walter Minto (1753–96*), co-author of a life of John Napier of Merchistoun, the inventor of logarithms. Minto provided an epitome of the end-of-the-century attitude toward Newton and mathematics, in *An Inaugural Oration, on the Progress and Importance of the Mathematical Sciences* (Trenton, 1788). In it he reviewed the history of the science from the time of the Greeks until the appearance of Sir Isaac, "a man without an equal in the history of human genius"; remarked that in more than sixty years of "the most enlightened period of the world" little had been added to Newton's work except "a superior degree of polish and strength"; and concluded with comments on the importance of pure mathematics. Independently of possible application, Minto asserted, the mathematical sciences "brighten and enlarge that reasoning power which forms the most distinguishing feature of man," improve the morals of leading men away from sensual objects to the purely intellectual,

inspire men with "a sense of order, of regularity, and of dignity," and, far from producing skeptics, teach that the universe is written in the language of geometry, "without the knowledge of which, the excellencies of the workmanship, and the skill of the great Artist, can be but imperfectly understood."[56]

PHYSICS AND ASTRONOMY

Newton, as Minto's statements show, was worshiped for his mathematical world-view, which gave physics and astronomy tremendous significance in the eighteenth century. Doubtless not all his worshipers understood his universe (how many today venerate Einstein without understanding him?), but of the passion to understand there can be no doubt. Greenwood's lectures, already described, were only the beginning of a flood of instruction in the so-called "experimental" philosophy, and of such a vogue for astronomical observations as had never been seen before and has scarcely been seen since.

John Winthrop, as might be expected, took over such tasks at Harvard, and once each year delivered the course of "near thirty lectures" which link him to Desaguliers and Greenwood, holding himself ready, meanwhile, "to endeavour to clear, at any time, by conversation with my pupils, such difficulties as lie upon their minds, relating to the several parts of the Mathematics, Natural and Experimental Philosophy."[57] The manuscript of his course as it was delivered in 1746 is in the Harvard archives.[58] Beginning with a definition of motion, Winthrop lectured upon the following topics: the mechanical powers, the lever, the pulley, the axis in Peritrochio, the inclined plane, the wedge, the screw, compound engines, the three laws of motion, gravity, attraction and cohesion, the power of repulsion, magnetism, electricity, fluids, optics, and astronomy. As this list reveals, "natural philosophy" was beginning to assume the

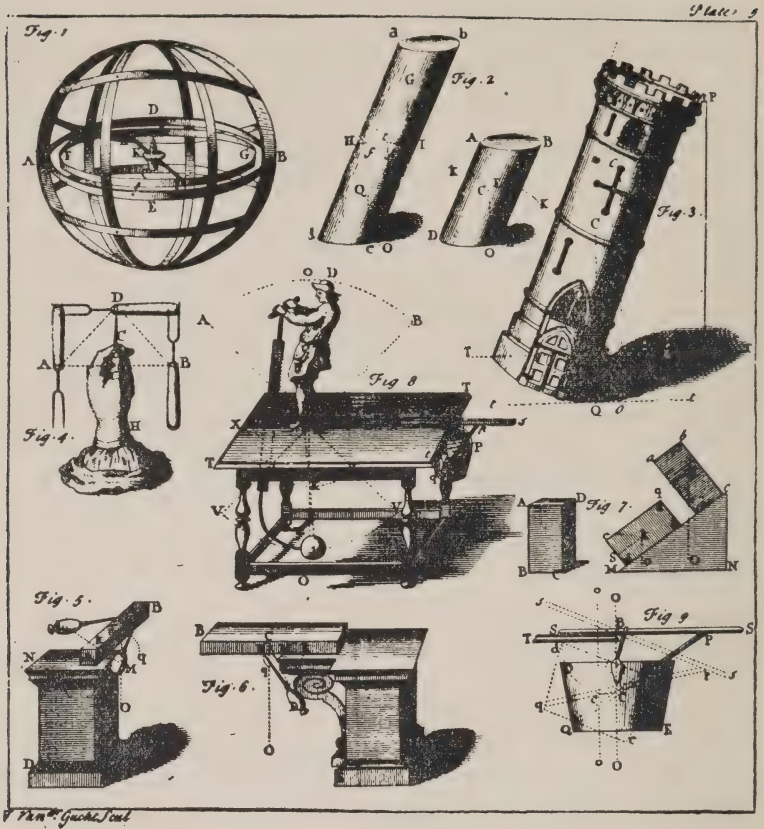


Plate illustrating the principle of the center of gravity, from J. T. Desaguliers' *Course of Experimental Philosophy*

shape of modern physics. In the course Winthrop used the following elaborate apparatus and such additions as had been made since the founding of the Hollis professorship:

Under the head of Mechanics, there were machines for experiments of falling bodies, of the centre of gravity, and of cen-

trifugal forces; the several mechanical powers, balances of different sorts, levers, pullies, axes in peritrochio, wedges, compound engines, with curious models of each in brass.

In Hydrostatics, very nice balances, jars, and bottles of various sizes fitted with brass caps, vessels for proving the grand hydrostatic Paradox, siphons, glass models of pumps, hydrostatic balance, &c.

In Pneumatics, there was a number of different tubes for the Torricellian experiment, a large double-barrelled Air-pump, with a great variety of recievers of different sizes and shapes, syringes, exhausting and condensing; barometer, thermometer, with many other articles.

In Optics, there were several sorts of mirrors, concave, convex, cylindric; lenses of different foci; instruments for proving the fundamental law of refraction; prisms, with the whole apparatus for the Newtonian theory of light and colors; the camera obscura, &c.[59]

Demonstrations were to some degree popularization, and Winthrop also lectured privately two days each week. Moreover, he engaged in investigations of his own, and has been called the first "productive scholar" on the Harvard staff.[60] Less than four months after his induction he was observing sun-spots.[61] Other astronomical and meteorological observations followed, many of them finding their way into print in the *Philosophical Transactions,* where his hypothesis of comets, regarded in his day as his most important paper, was first published. His study of the great earthquake of 1755 contained a wave theory of motion in the earth's crust, for which John Michell is sometimes given credit.[62] And in 1761 he skilfully enlisted the aid of the sailing-vessel owned by the province of Massachusetts, together with that of two members of the senior class at Harvard, and went off to Newfoundland to observe the Transit of Venus of June 6th—thus conducting the first excursion for astronomical observations by a member of any American college faculty.[63] By dramatic publicity, Winthrop

showed the practical importance of abstruse calculations, and enormously strengthened the position of the sciences. In 1775 and 1776, thanks to the influence of John Adams, he turned his mind to the technological problems of revolution, exploring colonial resources for the manufacture of gunpowder and cannon.[64] Winthrop, in short, was the prototype of the college professor of science as he has been known in recent years—on leave for the duration.

Not the least of Winthrop's contributions to teaching was his introduction of new textbooks in 1743. These included such relatively elementary works as Watts's *Astronomy,* Gordon's *Geographical Grammar,* and Ward's *Mathematics,* as well as the more elaborate *Natural Philosophy* of 's Gravesande.[65] The last-named book was adopted by Clap at Yale in the same year;[66] it was the standard textbook for about twenty years, and was then generally superseded by Benjamin Martin's *Philosophical Grammar,* used at Yale from 1760 to 1787, at Brown in the seventies, and at Dartmouth in 1792.[67] Martin was in turn displaced by William Enfield's *Institutes of Natural Philosophy, Theoretical and Experimental* (London, 1783; 1799), adopted at Yale in 1788 and at Harvard at about the same time.[68] Watts's *Astronomy* was generally replaced by James Ferguson's *Astronomy Explained upon Sir Isaac Newton's Principles* (3d ed., London, 1764) by the eighties.

As has been said, Winthrop also accumulated one of the best private scientific libraries of his time, a library which contained not only the older books on mathematics, astronomy, and geography, but four by Sir Isaac Newton himself, three by Desaguliers, three by 's Gravesande, and the commentaries on Newton by Benjamin Martin, Colin Maclaurin, and Henry Pemberton. Among his books, now at Allegheny College, is a copy of Joseph Priestley's *History and Present State of Elec-*

tricity, published in 1775, only four years before Winthrop's death. He "kept up."

Nothing is more indicative of Winthrop's place in Harvard College and in New England, however, than the aftermath of the burning of Harvard Hall in January, 1764. That catastrophe destroyed all the instruments which the college had inherited from the seventeenth century, all the machines provided by Thomas Hollis, and much new apparatus, including a number of reflecting telescopes. Yet, within a year, no fewer than 150 different individuals had donated apparatus for replacement. Among the instruments specifically named, some of them of great value, were an orrery, Hadley's quadrant, two telescopes (one of twenty-eight feet, the other a reflector), a solar microscope, three sets of globes, a barometer, and a magic lantern.[69]

Harvard's greatest rival in physics was probably William and Mary. There, in 1758, William Small became professor of natural philosophy and mathematics.[70] An enthusiastic and skilful teacher, Small made his subject both exciting and fashionable. His appointment, Jefferson wrote in his autobiography, "was my great good fortune, and what probably fixed the destinies of my life."[71] Although, in the light of the work of Greenwood and Winthrop, there is little ground for the statement that Small was the first to use the modern lecture system in America,[72] there is ample evidence of his invigorating influence. Jefferson went on to say that from Small's conversation he got his "first views of the expansion of science, and of the system of things in which we are placed," remarking also that Small introduced him to George Wythe and Francis Fauquier, (1704?–68*) the lieutenant-governor. The latter was a Fellow of the Royal Society. Small returned to England in 1762 or 1763, and has a place in history as an associate of

James Watt in the perfection of the steam engine, but his services to William and Mary did not end abruptly. In 1768 he accepted a commission to purchase between $2,000 and $3,000 worth of apparatus for the college, at a time when $150 was doubtless sufficient to keep a student in luxury for an entire year. Of this apparatus, which was in due time delivered, only a partial list survives,[78] but it shows the acquisition of a telescope, microscopes, prisms, an air-pump, barometers, compasses, machines for the demonstration of the laws of motion and mechanics, and an electrical machine. Allowing for its excellent condition and Small's good judgment, it is safe to say that it was comparable to the apparatus at Harvard.

Its principal user was the Rev. James Madison (1749–1812*), already encountered as a reformer of the curriculum. Madison was graduated from the college in 1771; two years later he was chosen professor of natural philosophy and mathematics and sent to England for further study; in 1777 he was elected president. He retained his professorship until 1784, when the Rev. Robert Andrews became professor of mathematics; thereafter Madison was president and professor of natural philosophy until his death in 1814. His reorganized curriculum, for which Jefferson claimed much of the credit, was put into operation soon after the Revolution. A student notebook of 1809 gives an opportunity to estimate his instruction. It suggests that he kept up with new subjects, turning his attention toward chemistry rather than toward astronomy, and that he was somewhat more theological in his purposes than Winthrop had been. Nevertheless, his course had in it elements familiar to the present-day student of physics. In outline it was as follows:

Introductory; of matter or bodies in general; Chemical Affinity; Gravitation; Magnetism; Motion; Central forces or doctrine of

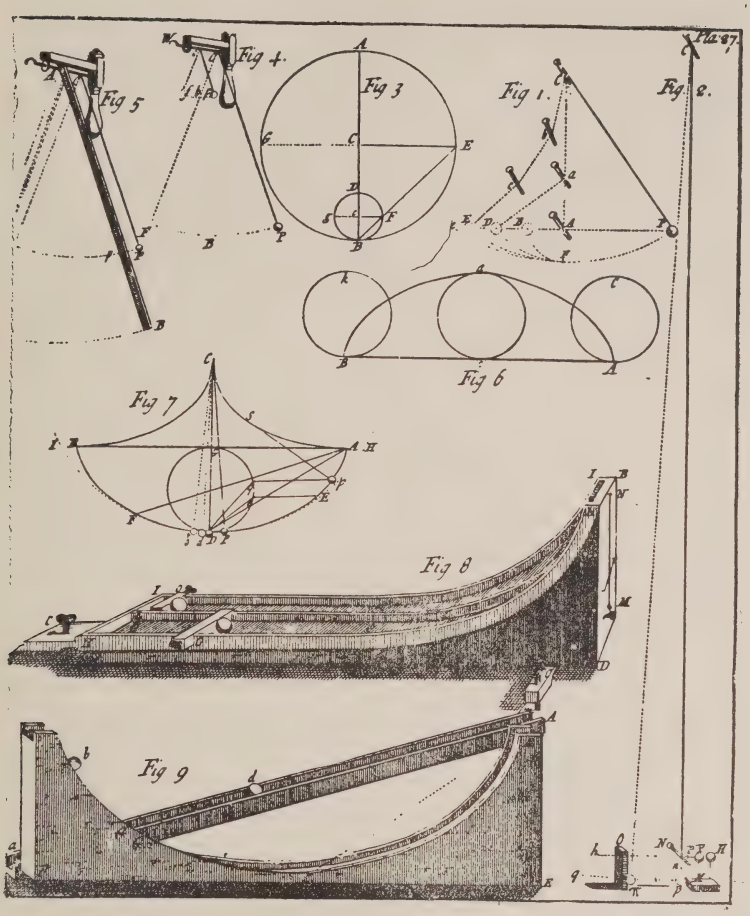


Plate illustrating movement of pendulums, etc., from J. T. Desaguliers' *Course of Experimental Philosophy*

circular motion; Of bodies falling perpendicularly; Of pendulums; Mechanical Powers; Compound Mechanics; Wheel carriages; Electricity; Of the two electricities; Of electricity communicated to electrics; Of the effects of electricity upon plants, vegetables, etc.; Galvanism; Pneumatics; Of the properties of air; Of air as necessary to combustion, etc.; Of heat; Introductory to airs; Of some of the gasses *(sic)* [oxygen, hydrogen, nitrogen]; Of Nitrous air [including also 'Of the Carbonic acid, Of the analysis of atmospheric air']; Of Evaporation; Of Winds; Of Hydrostatics; Of the densities and specific gravities of bodies; Of Hydraulics; On Optics, Light; Colours; Of the manner in which rays of light are refracted in passing through glasses of different forms; Of the senses in general; Of Microscopes and Telescopes.[74]

Further knowledge of the content of Madison's course may be gained from Samuel Miller's listing of works "generally referred to, and recommended," in 1803:

ROWNING. (John Rowning, *A Compendious System of Natural Philosophy*, London, 1744; 2 vols., 1753.)

HELSHAM. (Richard Helsham, *A Course of Lectures in Natural Philosophy*, London, 1739; 1743.)

MARTIN. *(Philosophia Britannica*, or the *Philosophical Grammar.)*

DESAGULIERS. (Probably *A Course of Experimental Philosophy*, London, 1735; 1738.)

MUSCHENBROEACK. (Peter de Musschenbroeck, *Elementa Physica*, Leyden, 1734; trans. by Colson as *The Elements of Natural Philosophy*, 2 vols., London, 1744.)

CAVALLO. (Tiberius Cavallo, *A Complete Treatise of Electricity*, London, 1777; 3 vols., 1795.)

ADAMS. (George Adams, *Micrographia Illustrata, or the Knowledge of the Microscope Explained*, London, 1746.)

LAVOISIER. (Antoine Laurent Lavoisier, *Traité elementaire de chimie*, Paris, 1785; 2 vols., 1791; trans. by Robert Kerr, Edinburgh, 1790; 1793.)

CHAPTAL. (Jean Antoine Claude Chaptal, *Elemens de chimie*, 3 vols., Montpelier, 1790; trans., 3 vols., London, 1791.)

Some of these books may be found in almost any of the older college libraries.

Similar courses in natural philosophy were instituted in the period of established pattern in most of the other colleges, with somewhat varied success. John Kemp at Columbia, provided with "an elegant and expensive apparatus," gave a course of about 600 experiments, open under certain conditions to non-students.[75] He divided it into eight parts: mechanics, strictly so called; hydrostatics; hydraulics; pneumatics; optics; electricity; magnetism; and astronomy. Kemp had been trained as an engineer; his strong practical bias has already been mentioned. One member of the class of 1753 at Princeton studied Gordon's *Geographical Grammar* and Watts's *Astronomy* as a freshman and, as a sophomore, attended a course of twelve lectures in natural philosophy by Lewis Evans (1700?–56*), the Philadelphia geographer, who used apparatus hired from James David Dove, master of an academy for young ladies.[76] In 1760 President Davies expressed regret that "in the study of Mathematics and the Newtonian Philosophy" Princeton students had but "very imperfect Helps, either from Books or Instruments."[77] Gradually, however, apparatus was accumulated, until by 1800 the college estimated its value as £535, invested in two telescopes, a theodolite, an air-pump, convex and concave mirrors, a magic lantern, magnetical, hydrostatical, and microscopical apparatus, a "mahogany case of chemical tests," the Torricellian experiment, a "two fall guinea and feather apparatus with long glass receiver," and many other items.[78] Provost Smith's scheme at Pennsylvania included, as has been said, extensive work in natural philosophy as well as in chemistry, agriculture, and natural history. The textbooks suggested were Rowning, John Keill's *Astronomy* (London, 1721; 1724), and Shaw's edition (London, 1753?) of Hermann

Boerhaave's *Chemistry,* a widely popular work first published at Paris in 1724.[79] Smith's voluminous list of supplementary suggestions included Helsham, 's Gravesande, Desaguliers, Musschenbroek, Martin, Maclaurin, Rohault, and several other works. A course of experiments was doubtless a regular part of the Pennsylvania program (in 1755 £150 was appropriated for the purchase of apparatus for exhibiting experiments),[80] but not much seems to be known about it before the time of the reorganization of the university in 1779. The Rev. John Ewing (1732–1802*) then became provost and professor of natural and experimental philosophy.[81] The course which he was already giving eventually appeared in print, edited by his colleague, Robert Patterson, as *Plain Elementary and Practical System of Natural Experimental Philosophy* (Philadelphia, 1809). Like Kemp at Columbia, Ewing appears to have stressed utilitarian applications. Astronomy was also particularly favored in Philadelphia, and David Rittenhouse (1732–96*), the leader of his generation in that science, was professor of astronomy for a few months in 1779–80.[82] In general, however, the scientific interests in Philadelphia were centered around the American Philosophical Society rather than around the University.[83]

Both Yale and Brown attempted to strengthen the work in natural philosophy by using part-time professors, who came to the college to give lectures at more or less regular intervals. The diary of Ezra Stiles is a remarkable account of the importance of such lectures in the college program, but he, as president, was constantly forced to act as substitute. The most interesting visitor at Brown (then Rhode-Island College) was the well-to-do industrialist and amateur architect, Joseph Brown (1733–85*), of the family whose benefactions led to the change in name of the institution. He served as professor of experi-

mental philosophy in 1784–85.[84] At both institutions apparatus was accumulated rather haphazardly, and not always properly cared for; telescopes, for example, showed a deplorable tendency to rust. Yet there was constant effort on the part of interested professors, here and at other colleges, to provide the equipment necessary for demonstration teaching.[85] Three years before the first classes met at the University of North Carolina a committee of the trustees recommended that steps be taken to procure apparatus for experimental philosophy and astronomy, including "a set of globes, barometers, thermometers, microscope, telescope, quadrant, prismatic glass, air pump, and an electrical machine."[86]

One type of apparatus, as a matter of fact, roused the first colleges to competition foreshadowing that of the present day, when observatories and atom-smashers are pearls in the crowns of universities. The eighteenth century set great store by orreries—machines built to display the bodies of the solar system in their relative sizes and positions. Thomas Clap constructed a simple one for Yale in 1743.[87] That which David Rittenhouse built in 1767 was the mechanical wonder of its age; Jefferson believed that Rittenhouse had by imitation approached nearer his Creator "than any man who has lived from the creation to this day."[88] Pennsylvania appears to have been smugly sure that Rittenhouse's orrery would be an ornament of its scientific rooms, and was more than a little irked when President Witherspoon of Princeton whisked it away to New Jersey.[89] So Rittenhouse made another for Pennsylvania. The friends of Harvard promoted a state lottery so that the college could acquire the orrery constructed by Joseph Pope, a Boston watchmaker, in 1786, and Pope was honored for his skill by election to the American Academy of Arts and Sciences.[90] At the time of Harvard's tercentenary celebration the orrery was

located, after extended search, in the basement of Harvard's music building.

All in all, there is much reason to think there was some justice in the complaint of an anonymous versifier in *The American Magazine and Historical Chronicle* for February, 1744, whose "Epistle from Cambridge" sets forth the plight of the lover of poetry in an eighteenth-century college. After saying that he no longer reads Virgil, Milton, Horace, Congreve, Cowley, Addison, Prior, Pope, and Homer, he gets to the way in which he actually spends his time:

> Now algebra, geometry,
> Arithmetick, astronomy,
> Opticks, chronology, and staticks,
> All tiresome parts of mathematicks,
> With twenty harder names than these
> Disturb my brains, and break my peace.
> All seeming inconsistencies
> Are solv'd by A's, or solv'd by B's;
> Our senses are depriv'd by prisms,
> Our arguments by syllogisms.
> If I should confidently write,
> This ink is black, this paper white,
> They'd contradict it, and perplex one
> With motion, light, and it's reflection,
> And solve th' apparent falshood by
> The curious structure of the eye.
> Shou'd you the poker want, and take it,
> Glowing as red as fire can make it,
> And burn your finger, or your coat,
> They'd falsly tell you, 'tis not hot.
> The fire they say has in't, 'tis true,
> The power of causing pain in you,
> But no more heat's in fire, that heats you,
> Than there is pain i' th' stick that beats you.
> . . . . . .

We're told how planets roll on high,
How large their orbits, and how nigh;
I hope in little time to know,
Whether the moon's a cheese, or no;
Whether the man in 't (as some tell ye);
With beef and pudding fills his belly;
Why, like a lunatick confin'd,
He lives at distance from mankind;
Who at one resolute attack
Might whirl the maggot off his back;
Or like a maggot in a nut
Full bravely eat his passage out.

Of the conspicuousness of physics and astronomy, at certain stages in the college course, there can be no serious question.

Occasionally, as has been suggested, the course in natural philosophy split into parts, amoeba-like, and new subjects emerged. In this process the greatest impetus came from a force not heretofore prominently mentioned—the medical schools. Both botany and chemistry developed, as separate sciences, in close relation to the study of medicine, and, with anatomy and physiology, first appear in those American colleges which were closely associated with early medical education—Pennsylvania, Columbia, and Harvard.

BOTANY AND ZOOLOGY

Natural history, which had disappeared soon after its first appearance as "the nature of plants" on Dunster's curriculum, returned in Provost Smith's plan of 1756. In the following year King's appointed a professor of mathematics and natural history, but there is no assurance that he taught the latter subject.[91] Then, in 1768, the Pennsylvania medical school appointed Adam Kuhn as professor of materia medica and botany. Although Kuhn had been a student under Linnæus in Sweden, he does not seem to have been much of a spur to botanical

or zoological studies, and nothing is known of his teaching.[92] In 1789, however, Pennsylvania made one of its own graduates, Benjamin Smith Barton (1766–1815*), professor of botany and natural history. Barton was the first resident professor of his subject in an American arts college, although it is uncertain whether or not arts students actually attended his lectures. In 1803 he published an *Elements of Botany,* said to be the first textbook on the subject issued in the United States and in its time exceedingly popular. In his lectures, however, to judge from a student notebook dated 1805 and now in the Library of Congress, Barton devoted much time to topics other than botany.[93] He spoke on zoology, botany or phytology, mineralogy, geology, hydrography, and meteorology.

The trend toward a new emphasis on natural history is observable elsewhere. Jefferson said that in 1779 the Visitors at William and Mary added the field of natural history to the duties of the professor of mathematics and natural philosophy.[94] In 1784 Benjamin Waterhouse (1754–1816*), a Newport youth who had taken his M.D. at Leyden, was appointed professor of natural history, without pay, at Rhode-Island College, one year after he had become professor of the theory and practice of physic in Harvard's newly formed medical school.[95] Waterhouse apparently commuted to Providence in 1785 and 1786, and he may have lectured there even later. In all probability he gave the same course which he delivered at Harvard from 1788 until his dismissal in 1809, and of which several lengthy outlines are extant.[96] Waterhouse dealt with the classification of the sciences, geology, botany (with particular attention to agriculture), zoology, the chain of being, man, and mineralogy. Those students who attended his lectures paid a special fee. His work was remarkable for its broad, philosophical approach, and it was probably sounder science than

was Barton's. Both men obviously owed much to the older discipline of natural philosophy.

At Columbia, Henry Moyes was appointed professor of natural history in the faculty of medicine in 1785, but he seems to have taught for only one year.[97] Then, in 1792, Samuel Latham Mitchill (1764–1831*) was called to a professorship of natural history, chemistry, agriculture, and other arts depending thereon.[98] The trustees outlined the duties of this post under six heads: geology, meteorology, hydrology, mineralogy, botany, and zoology. W. M. Smallwood regards Mitchill's teaching, as exemplified in a syllabus of his course which was published in 1809, as superior to Barton's, although not always impressive for scientific thinking.[99] Mitchill too found most if not all of his students among those in the medical school. Princeton, finally, appointed John Maclean (1771–1814*) as professor of natural history in 1796, but Maclean's interests seem to have been chiefly in chemistry.

Only a handful of students, and those largely in the medical schools, had much acquaintance with the biological sciences. It is easy to understand the enthusiasm of Ezra Stiles when Manasseh Cutler showed up in New Haven in 1787. Let Cutler tell the story:

I sent for my trunk and showed the Doctor and his lady, and the young ladies, my botanical apparatus and books, with which they were all highly pleased, having never seen any thing of the kind before. I had collected a number of flowers the day before, which I had not had time to examine. They were perfectly fresh in my botanical box. From them I gave a short lecture on the parts of fructification, separating and exhibiting the parts at the same time, which was highly amusing to the company. The Doctor was extremely pleased with my "Hobby-horse," and was determined to mount him, and have a ride himself. I had to explain technical terms, and construe crabbed Linnaen Latin for an hour on a stretch. At

length a call to dinner put an end to my fatigue. But the "Hobby-horse" was introduced at table, and each of the company must have a ride in turn. After dinner I was determined to set out immediately, but there was no such thing as getting away. We returned to the microscope and plants.[100]

Botany and zoology as essential features of the college curriculum were still to come when the eighteenth century was over.

CHEMISTRY

The earliest mention of chemistry appears to be that in Provost Smith's curriculum of 1756.[101] A manuscript series of lectures on the subject, dating from about 1760 and probably written by Smith himself, shows that the subject was actually taught at Philadelphia.[102] Normally, however, it was a part of natural philosophy, as at William and Mary, and as it evidently was under Ewing at Pennsylvania later.

In the medical schools it was much more conspicuous. Between 1767 and 1776 King's boasted two professors of chemistry and materia medica—James Smith (1767–70) and Peter Middleton (1770–76). Samuel Bard (1742–1821*) was professor of chemistry in 1784–85 and 1786–87, with Moyes holding that title as well as that of professor of natural history in 1785–86. In 1792–94 Samuel Nicoll was professor of chemistry and the practice of medicine.[103] All of these men were physicians, and there is no hint that any was concerned with more than the essentials of chemical medicine. Bard was perhaps an exception; he had studied under William Cullen at Edinburgh and acquired unusual breadth of knowledge and of intellectual curiosity.[104]

The medical school at Philadelphia had a professorship of chemistry from its foundation in 1769, and of its five eighteenth-century incumbents—Benjamin Rush (1769–89), Caspar

Wistar (1789–91), James Hutchinson (1792–93), John Carson (1794), and James Woodhouse (1795–1809)—Rush (1745–1813*) and Woodhouse (1770–1809*) were distinguished chemists.[105] A syllabus prepared by Rush for "the use of the students of Medicine in the College of Philadelphia" is said to be the first book on chemistry by an American; Woodhouse's *The Young Chemist's Pocket Companion* (Philadelphia, 1797) appears to be the first book by an American describing chemical experiments and apparatus.[106] Woodhouse, moreover, was the founder in 1792 of the Chemical Society of Philadelphia, the first of its kind in the world. Even though Joseph Priestley failed to accept the invitation to join its staff in 1794 the Pennsylvania medical school has a leading place in the early history of American chemistry.

The first professorial appointment in chemistry in an arts college went to John Maclean, settled at Princeton in 1796.[107] A student notebook dating from 1806 provides means of gauging Maclean's instruction, for which he had been prepared at Edinburgh, London, and Paris.[108] A follower of Lavoisier, Maclean lectured on both dead and living matter, foreshadowing the later division of the subject into inorganic and organic investigation. He had accepted the further division of dead matter into simple and compound, but was understandably a long way from the periodic scale in his account of substances which could not be decomposed. Differences in terminology make it hard to speak with confidence of the level of Maclean's teaching, but he lectured on thirty-seven "simple" substances. Among them were twenty of the elements now recognized: oxygen, hydrogen, sulphur, phosphorus, carbon, "alumine," arsenic, tungsten, cobalt, bismuth, nickel, manganese, antimony, mercury, zinc, tin, lead, silver, gold, and "platina" or platinum. He included as simple substances, however, such compounds as

lime, soda, potash, barytes, and stontites, a number of acids, and, to stand as mute testimony of the state of the science of chemistry in his day, light and electricity.

Toward the end of the eighteenth century there was obviously widespread interest in the emerging field of chemistry. In addition to the lectures at the College of Charleston in 1793, already mentioned, Yale resolved in 1798 to institute a professorship of chemistry and natural history as soon as funds were available, and in 1802 Benjamin Silliman (1779–1864*) was elected.[109] With Silliman a new era in chemical science in America had its beginning.

GEOGRAPHY

The instruction in geography offers problems of peculiar interest. Before 1800 the subject was in what present-day geographers have called the gazetteer stage, that is to say, it began with a brief introduction to astronomy and then consisted of the compilation of as much general information on the various countries of the world as could be presented in the time or space at hand.[110] The astronomical portion was what is now described as mathematical geography and required celestial and terrestrial globes, which were used to demonstrate problems in geodesy and navigation.

Harvard juniors, as has been said, were supposed to read a "System of Geography" under the curriculum which is thought to have obtained about 1690. The rules for the Hollis professorship show that "dialling" and the use of the globes and of maps were among the topics handled by Greenwood and Winthrop, and it is worth recalling that much of Winthrop's interest in astronomical observation had a geographical purpose —the accurate determination of longitude and latitude. In most colleges geography was a sophomore subject, as much

history as anything, perhaps in some ways the equivalent of an orientation course. Columbia appears to have been the only college to recognize the field by professorial appointments. John Daniel Gross was professor of German and geography between 1784 and 1795 and one of John Kemp's titles in 1795–99 was professor of geography.[111] It was to be many decades before departments of geography became common in American universities.

The textbooks in geography were surprisingly uniform. Gordon's *Geographical Grammar,* introduced by Winthrop at Harvard in 1743, was being used at Princeton ten years later.[112] William Guthrie's *New Geographical, Historical, and Commercial Grammar,* first published at London in 1770, was used at Yale between 1774 and 1784, at Brown in 1783, and at Dartmouth in 1792.[113] After 1790 Guthrie was ordinarily superseded or supplemented by one of the books of Jedidiah Morse (1761–1826*), who developed his enthusiasm for geography while he was a tutor at Yale, and eventually became the first notable American geographical writer.[114]

VI

Libraries

The relations of books and libraries to the spread of scientific thought form a somewhat special problem, in which the chief difficulty is to establish actual use of a given book at a given time. The most striking example of the effect which books could sometimes create has already been described—the Yale reaction to the arrival of the Dummer library in 1714. Much more might be said, for there are available, in addition to numerous records of gifts and importations, printed catalogs of several of the college libraries, a number of systematic reading lists drawn up for the use of students, and some "commonplace books," in which student readers copied out quotations which they thought important enough to be worth the labor. Some of these sources of information have as yet been explored only slightly.

F. G. Kilgour has analyzed the Harvard catalog of 1723 and its two supplements of 1725 and 1735 for scientific titles, finding that they represent about nine per cent of the total number.[1] There are some strange gaps, the *Principia* for one, and much that from the viewpoint of living science was already deadweight. But the Harvard and Yale libraries contained many scientific classics which would be displayed proudly by any custodian of rare books today.

Notebooks kept by Thomas Robie, John Winthrop, Nathan Prince of the class of 1718, and Jonathan Belcher of the class of 1728, show that the most conscientious students at Harvard

noted or copied passages from the *Philosophical Transactions,* William Derham's *Physico-Theology,* Cotton Mather's *The Christian Philosopher,* John Ray's *Wisdom of God Manifested in the Works of the Creation,* Thomas Burnet's *Sacred Theory of the Earth,* Varenius's *Geographia Generalis,* and many books on mathematics.[2] The evidence suggests a tendency to use popular introductions to knowledge rather than technical scientific works, but any defensible conclusion on this point must await further study, and the examination of similar materials at institutions other than Harvard.

The only curricula which referred students to supplementary reading in the field of scientific studies were Provost Smith's and President's Madison's, and it is hardly safe to take recommendations as an indication that the books were actually read. The same thing may be said of the frequently quoted advice in Cotton Mather's *Manuductio ad Ministerium* (Boston, 1726), an outline of studies for students preparing for the ministry:

> What we call NATURAL PHILOSOPHY, is what I must encourage you to spend much more Time in the study of . . . as thorough an Insight as you can get into the *Principles* of our *Perpetual Dictator*, the incomparable Sr. *Isaac Newton*, is what I mightily commend unto you.
> Be sure, The *Experimental Philosophy* is that, in which alone your Mind can be at all established.[3]

Other noteworthy suggestions for reading were made by Thomas Clap, in the classified catalog of the Yale College library which he published in 1743, and by Samuel Johnson in the 1744 edition of his *Introduction to the Study of Philosophy.*[4]

It should be added that by later standards the college libraries were exceedingly tiny. As Samuel Miller's census has shown, Harvard, with between 13,000 and 14,000 volumes, was by far

the largest in 1800. Yale ranked second with between 3,000 and 4,000 books. Dartmouth, Brown, Columbia, William and Mary, and even Dickinson, reported about 3,000 volumes each. Pennsylvania had only 1,000. Princeton did not commit itself, but Miller remarked that the library was "small." It had been rebuilding rapidly after the Revolution, only to lose about 3,000 volumes again when Nassau Hall burned in 1802.[5] The city colleges, notably Pennsylvania and Columbia, had access, of course, to collections other than their own, as they still have. Like Princeton, they suffered severe losses during the Revolution.

A census of scientific books in America in the seventeenth and eighteenth century would contribute to one's appreciation of the speed and nature of the diffusion of knowledge, but there is none as yet available and the task of compilation is enormous.

VII

The Effects

One of the unsolved problems of historiography is how to evaluate with satisfying accuracy the effect of a particular intellectual tradition upon the society of which it is a part. It is possible to find out, after a fashion, what those persons who wrote books thought, and occasionally how they came to think it. What the average state of knowledge was at a given point in history remains almost pure guesswork. The study of school textbooks and the accumulation of allusions in general literature to matters assumed to be common knowledge are helpful but by no means conclusive guides. No statistical technique seems quite to supply the need for some way of gauging the effects or the functions of a given idea at a given time.

In the absence of method for such a purpose, one must fall back upon the examination of minds which, in the perspective provided by time, seem most representative, or upon the exploration of the resistance to change by groups or individuals who felt themselves threatened by the drift of the times. David Masson's *Milton* is an example of the former procedure, and scarcely equalled even yet as an introduction to Puritanism; an excellent example of the latter method is Andrew Dickson White's *History of the Warfare of Science with Theology in Christendom.* On the much smaller scale of the present study, these procedures may be tentatively applied. What was the attitude toward science of the representative alumni of the

colleges with which these pages have dealt? What evidence is there of opposition, other than a conservative inertia, to the expansion of scientific studies which has been described?

The most conspicuous and probably the most representative alumni of seventeenth-century Harvard were the two Mathers. Increase was a member of the class of 1656; his son, Cotton, was graduated in 1678. Despite their notoriety in connection with the Salem witchcraft episode, and their whole-hearted acceptance of the doctrine of special providences (which now seems almost the antithesis of science), there is abundant evidence that the Mathers were enthusiastic, if not especially shrewd, students of the new knowledge.[1] They welcomed science largely because they saw, or thought they saw, that it promised to be useful as a bulwark for religion. Harvard had not taught them to be on their guard against it, nor is there any substantial basis for the belief that Harvard so taught any of its graduates in the first phase of its existence.[2] Increase Mather went so far as to try in 1683 to organize a philosophical society to meet fortnightly to discuss "Improvements in *Philosophy* and Additions to the Stores of *Natural History.*"[3] His son, in *The Christian Philosopher* (London, 1721), deliberately set out to "demonstrate, that *Philosophy* is no *Enemy,* but a mighty and wondrous *Incentive* to *Religion,*"[4] and it needs only a glance at the book to see that he meant natural philosophy, that is to say science. His intention was eminently suitable in an American Fellow of the Royal Society.

Cotton Mather's statement, however, suggests that science had its enemies. Who were they? Not the college men in New England, apparently, but the obscurantists, the extreme Puritans in Old England who distrusted university training because they thought it made men supercilious, if not openly contemptuous, of religious enthusiasm and the more violent

forms of evangelical zeal. William Dell, for example, installed as Master of Gonville and Caius College, Cambridge, in 1649, thought that the divinity student should study only the Bible, and said so in a sermon of 1653 which attacked schools of "humane learning" as "stews of Antichrist" and "houses of lyes."[5] Dell was answered at a Harvard Commencement two years later by President Charles Chauncy.

"I do much desire," Chauncy wrote,

> that the opposers of schools & universityes would speak plainly what they mean by humane learning, then wee should easily come to some conclusion.[6]

They may mean, he continued, one of two things: either (1) that learning delivered by the heathen authors or philosophers; or (2) all arts other than theology. If they mean the former, he felt that it would be a great oversight to ignore what the heathen had learned from the light of nature. If they mean the latter—and here is the curious reason why science was not distrusted at this era at Harvard—

> I will be bold to affirme that these [physics, ethics, politics, economics, rhetoric, astronomy, etc., and the learned tongues of Latin, Greek, and Hebrew] in the true sense and right meaning thereof are Theologicall & Scripture learning, and are not to be accounted of as humane learning. For who can deny, that the first & second chapters of *Genesis*, and many chapters in *Job* and the *Psalms*, and diverse other places of holy Scripture, do afford excellent and sure grounds for natural Philosophy, and a just systeme thereof; . . . And where are to be found such *Ethicall*, *Politicall*, or *Morall* precepts, as are to be found in holy Scripture?[7]

The fundamental purpose of learning, in other words, was to enable the Christian minister and gentleman to understand the Word of God, and the American Puritans of the first generation had not the slightest fear that learning could be dangerous.

To such self-confidence the Mathers and most Harvard graduates before 1690 were apparently accustomed.

Criticism of science and an awareness of areas of conflict between faith and scientific rationalism begin to appear between 1690 and 1740, perhaps because of echoes in America of the English controversy over Deism,[8] or as a result of the visits of George Whitefield, the evangelist, and the beginnings of Methodism. If the course of thought had continued along a straight line of increasing rationalism, the memorable figure of the college generation which produced Winthrop and Clap would perhaps have been Charles Chauncy, (1705–87*) of the class of 1721 at Harvard, unquestionably the foremost clergyman of his time in Boston.[9] Chauncy went the way of scientific rationalism, ended his life as both a Unitarian and a Universalist, and in what is perhaps his most important book remarked that God

> does not communicate either being or happiness to his creatures, at least on this earth, by an *immediate* act of power, but by concurring with an *established course of nature*. What I mean is, he brings creatures into existence, and makes them happy, by the intervention of second causes, operating under his direction and influence, in a *stated*, *regular*, *uniform* manner.[10]

Chauncy the rationalist was not, however, the central figure among the graduates of American colleges in the transition period of scientific instruction. The men who stand out as successors to the Mathers were both products of Yale—Samuel Johnson of the class of 1714 and Jonathan Edwards of the class of 1720. Both unquestionably understood the New Science as the Mathers never did. Both were in their formative years close students of the Newtonian philosophy. Neither went all the way with Charles Chauncy. Johnson followed Berkeley, the English philosopher and divine who resided at Newport in

1728–31, into philosophical idealism, and later relapsed into a far less tenable position, actually repudiating Newtonianism in favor of the anti-scientific thought of the followers of John Hutchinson, author of *Moses' Principia* (London, 1724).[11] Edwards directed one of the keenest intellects which has as yet appeared in America toward the reaffirmation of Calvinism and, while not actually anti-scientific, was scarcely encouraging to the study of nature.[12] Why did these men lack the enthusiasm for science which was displayed by their predecessors?

The easy explanation is that, allied by training and profession to the clerical order, they perceived the threat to that order in the New Science, and, with notable success, turned men's minds to the reconstruction of old patterns. The trouble with this explanation, useful as it is in describing the tenacious orthodoxy for which Connecticut was long renowned, is that it assumes a measure of second-sight which neither Johnson nor Edwards seems to have had.

When one turns to minor writers, the causes of the break in the line of development of scientific rationalism appear more clearly. Comments by Joseph Sewall and Thomas Prince, of the Harvard class of 1707, by John Barnard, who was graduated in 1700, and by Thomas Foxcroft of the class of 1714, suggest that the adjustment to new knowledge, achieved so readily by Robie, Greenwood, and Winthrop within the college, was sometimes difficult outside, if it also demanded the repudiation of older ideas. Sewall and Prince, in 1726, praised Samuel Willard for his bulky *Body of Divinity,* but feared that some readers might

> find the Author less exact in his *Philosophical Schemes & Principles,* which happen to be of a more ancient Date, and not so suited to the Opinions reigning in the present Age. In anticipation of which we need only observe, that in such things as these every Person is intirely left to his own Freedom without

Offence; that the internal Nature of Things being so extreamly incluse and hidden, many of our *Philosophical Schemes* have been by mere *Hypotheses* subsisting only in the Imaginations of Men, and being unsoundly rais'd from a few imperfect Observations of the Appearances and Events of Nature, have been successively thrown out by *others* as unstable as they.[13]

Religion, they concluded, "will for ever remain the same thro' all successive Changes of Philosophy." In 1738 Barnard, defending the Congregational form of church government, reminded his readers ever to subject philosophy to divinity:

Philosophy is but the result of *human Understanding*, and Reasoning; Divinity, I mean what turns upon Revelation, flows directly from the Divine Mind: and therefore, tho' Philosophy be a fine Accomplishment, and a great Improvement of our rational Powers, yet look upon it . . . but as an *Hand-maid* unto Divinity; . . . This will keep you from corrupting the Truths of the Gospel with vain Philosophy, after the Traditions of Men, or repudiating Divinity, and denying the Truth, because it is inexplicable by the Rules of Philosophy.[14]

And Foxcroft, in his contribution to the Whitefield controversy, took as his motto a paragraph from Isaac Watts's *Humble Inquiry* (1731):

You are not to stand up here *(in the Pulpit)* as a Professor of ancient or modern Philosophy, nor an usher in the School of *Plato*, or *Seneca*, or Mr. *Lock:* but as a Teacher in the School of CHRIST.—*Thus saith the Prophet*, or *Thus saith the Apostle*, carries greater Weight with it both to convince and persuade, than a long Series of *Demonstrations* from remote *Principles*, tho' they should be firm and strong as those of *Euclid*, or *Sir Isaac Newton*.—'Tis the vain Exaltation of *ruin'd Nature*, that makes the Gospel so despis'd in our Age.[55]

Remarks such as these suggest the beginnings of what is now called Fundamentalism. Some minds, evidently, found the successive overthrowing of Aristotle and Descartes unsettling and, far from certain that all knowledge, in true sense

and right meaning, is theological knowledge, retreated into the separation of science from theology, for which they had, of course, much precedent. The conflict which was to come in the nineteenth century over geological and biological world-views was implicit early in the eighteenth, but only a few men spoke out of their conscious conviction that the exaltation of "ruin'd nature" was a threat to faith. As time went on, more and more men so spoke their minds.

At first thought, it seems unwise to attempt much generalization about American college graduates in such troubled times as those beween 1740 and 1800. Out of Harvard in that period came such varied types as the first of the famous Adamses, John and John Quincy, Royall Tyler the dramatist, and William Ellery Channing. Yale's galaxy of Congregational clergymen and Federalist politicians contained also the explosive Joel Barlow, author of *Advice to the Privileged Orders.* James Madison, Philip Freneau, and Hugh Henry Brackenridge, classmates at Princeton, were shaped to no uniform pattern. Columbia and Pennsylvania, with John Jay, DeWitt Clinton, and Francis Hopkinson among their graduates, offer no shining examples of the shaping effects of a utilitarian ideal, unless we count Alexander Hamilton, who did not complete his course. The pride of William and Mary, Thomas Jefferson, turned to the law without a B.A. degree, and there is something a little tenuous in remarking that its president once certified to George Washington's competence as a surveyor. From this distance, in short, it seems that the colleges were graduating Calvinists and Deists, Tories and Whigs, Federalists and Republicans, with about the same moulding to a common type which we can observe today, which is to say exceedingly little.

When the attitude of these two generations toward science is considered, however, the complete triumph of Newtonianism

is clear enough. The world-view of Clap and Winthrop and Small was shared by these men almost without exception. That is not to say, to be sure, that they acquired it wholly in college; it was easy enough to absorb outside. Freneau expressed, a little more Deistically than was perhaps the norm, in his poem "On the Uniformity and Perfection of Nature":

> Who looks through nature with an eye
> That would the scheme of heaven descry,
> Observes her constant, still the same,
> In all her laws, through all her frame.
>
> No imperfection can be found
> In all that is, above, around,—
> All, nature made, in reason's sight
> Is order all and *all is right*.[16]

It is not hard to believe that men whose training led them to such conclusions should not only be typical products of the Age of Enlightenment, but should also approach the eternal puzzle of government with more self-confidence than most persons can command in the twentieth century. There is something, surely, in the suggestion by Woodrow Wilson and others that the system of checks and balances which lies at the heart of the American Constitution was in part the result of a widespread acceptance of the Newtonian theory of the universe.[17] Quite possibly J. G. Crowther is right in thinking the Constitution "an example of the dangers of the misapplication of scientific ideas by politicians who do not properly understand them," as frightening from some aspects as the present-day use of "false biological theories of human beings" to justify persecution and exploitation of non-Aryans. Men like John Adams, whose *Defence of the Constitutions of Government of the United States against the Attack of Mr. Turgot* (1787) is the best example of the ideas of mechanics applied to politics,

thought of society as a microcosmic universe, in which laws of cohesion and repulsion analogous to those of the physical world operated according to the arrangements of their creator, the wise maker of constitutions. In a very real sense, we in the United States still live under the Newtonian system.

Despite such applications of scientific thought, one can also perceive the persistence of an undercurrent of suspicion of science. It found its chief expression in the warfare against the Deists, which reached its climax just before the end of the century. Writer after writer cautioned the reading public against permitting the study of nature to supplant true religion or undermine morality. Although never, perhaps, a direct attack on science, the opposition to Deism was clearly based upon fear that the scientific advance might be misguided. In 1799, for example, John Mellen, of the Harvard class of 1770, began his Dudleian lecture upon natural religion as follows:

> The subject of this Lecture assumes a peculiar degree of importance, at the present day, when the foundations of natural, as well as revealed religion, are so boldly and virulently attacked, by an impious and athetistical philosophy;—a philosophy which would exalt *nature* to the throne of NATURE'S GOD; and which, under the pretence of destroying superstition, and freeing mankind from unreasonable restraints, opens the floodgates of the vilest passions, and levels those barriers, on which the security of social order and happiness essentially depends.[18]

Similar pronouncements could be cited by the dozens.

By the end of the eighteenth century, however, opposition or no opposition, "science" had become a word to conjure with. Its high estate in the colleges may be witnessed finally by *An Oration, on the Importance of Science and Religion, Particularly to American Youth,* pronounced at the Commencement of Rhode-Island College in 1798 by Andrew Dexter, Jr., A.B.

One would think, in reading it, that the fleets of Napoleon had sailed against the United States rather than against Egypt.

Behold! that fell demon, Atheism, issues from night and chaos, demolishes the government of France, and erects his throne upon its ruins. While he vociferates *liberty* and *equality*, he brandishes the thunderbolts of *despotism*, and stains the charter of freedom with the blood of its martyrs. Unsatiated with the spoils of one kingdom, with giant strides he encompasses Europe, destroys the monuments of art, tramples upon the sons of Science, tears down the altars of Religion, and deluges the world in blood. The earth trembles, the sky blackens—the monster approaches, and extends his arms to America. She, secure in native innocence, averts with scorn his foul embrace, and reposes her confidence in heaven and the unanimity of her sons. The voice of Science and Religion cries, to arms, to arms. Great WASHINGTON leaves the shades of retirement, draws the sword of death, and points to victory. The indignant shades of WARREN and MONTGOMERY start from their tombs, point at the wounds of their country, and cry aloud, revenge for our injured rights! My Brothers, swear to guard from profanation the altars of your Religion and Liberty. Rally with your fathers around the fortress of independence, and nobly resolve to *defend* it—or *die*. Alas! should you fall, your tomb would be the tomb of Science, of Religion, of Liberty, of America, and Man.[19]

Scientific thought in the American colleges had had, it would seem, perceptible, and sometimes strange, results.

NOTES

I. VALUES IN THE HISTORY OF SCIENCE

[1]A. Wolf, *A History of Science, Technology, and Philosophy in the 16th & 17th Centuries*, New York, 1935, p. 54.

[2]Some exception should be made to portions of the long series of *Contributions to American Educational History*, which appeared under the general editorship of H. B. Adams between 1887 and 1903, as Circulars of Information of the United States Bureau of Education. These volumes, compiled by many hands, were primarily concerned with the current status of educational institutions in the various states, but some of the authors were much interested in the history of curricula, instruction, and textbooks.

II. THE FIRST AMERICAN COLLEGES

[1]The most important omission is Rutgers, which was first chartered as Queen's College in 1766. Between 1795 and 1807, however, it was not in operation as a college. See D. D. Demarest, "Rutgers College," in David Murray, *History of Education in New Jersey* (Contributions to American Educational History, ed. H. B. Adams, No. 23), Washington, 1899, pp. 287–302, and W. H. S. Demarest, *A History of Rutgers College, 1766–1924*, New Brunswick, 1924. Other omissions are Washington and Lee (founded as Liberty Hall Academy at Lexington, Virginia, in 1782), the University of Vermont (chartered in 1791 and granting its first degrees in 1804), and the University of Tennessee (chartered as Blount College in 1794 and granting its first degrees in 1806). See D. G. Tewkesbury, *The Founding of American Colleges and Universities before the Civil War* (Columbia University Contributions to Education, Teachers College Series, No. 543), New York, 1932. Tewkesbury's bibliography contains numerous works on the individual colleges which I have been unable to consult.

[2]See G. T. Little, "Bowdoin College," in E. W. Hall, *History of Higher Education in Maine* (Contributions, ed. H. B. Adams, No. 33), Washington, 1903, pp. 41–94, and Nehemiah Cleaveland and A. S. Packard, *History of Bowdoin College*, Boston, 1882. According to *The Americana Annual, 1943*, Bowdoin had in 1941–42, the last moderately normal year before World War II, a faculty of sixty-three, a student body of 623, and a library of 190,000 volumes.

[3]See C. B. Wright, "A Brief History of Middlebury College," in G. G. Bush, *History of Education in Vermont* (Contributions, ed. H. B. Adams, No. 29), Washington, 1900, pp. 169–85. In 1941–42 Middlebury had a faculty of sixty-seven, a student body of 815, and a library of 142,000 volumes.

[4]See C. F. Himes, "Dickinson College," and Theodore Appel, "Franklin and Marshall College," in C. H. Haskins and W. I. Hull, *A History of Higher Education in Pennsylvania* (Contributions, ed. H. B. Adams, No. 33), Washington, 1902, pp. 42–82. In 1941–42 Dickinson had a faculty of thirty-seven, a student body of 526, and a library of 64,464 volumes, Franklin and Marshall a faculty of fifty, a student body of 856, and a library of 90,000 volumes.

[5]See B. C. Steiner, *History of Education in Maryland* (Contributions, ed. H. B. Adams, No. 19), Washington, 1894, pp. 229–45.

[6]Students were first taught at Georgetown in 1791; whether or not degrees were conferred in the eighteenth century I have been unable to discover. In 1940–41 the university had a faculty of 586, a student body of 2,706, and a library of 200,000 volumes.

[7]See Colyer Meriwether, *History of Higher Education in South Carolina* (Contributions, ed. H. B. Adams, No. 4), Washington, 1889, and J. H. Easterby, *A History of the College of Charleston, Founded 1770*, Charleston, 1935.

[8]See C. E. Jones, *Education in Georgia* (Contributions, ed. H. B. Adams, No. 5), Washington, 1889.

[9]Of the voluminous literature on the history of Harvard see especially: G. G. Bush, *History of Higher Education in Massachusetts* (Contributions, ed. H. B. Adams, No. 13), Washington, 1891, pp. 21–224; Josiah Quincy, *The History of Harvard University*, 2 vols., Boston, 1840; three recent books by S. E. Morison, *The Founding of Harvard College*, *Harvard College in the Seventeenth Century*, and *Three Centuries of Harvard*, all published at Cambridge in 1935–36; and J. L. Sibley, *Biographical Sketches of the Graduates of Harvard University* (cited hereinafter as "*Harvard Graduates*"), 3 vols., Cambridge, 1873–85, with the continuation by C. K. Shipton still in progress. In 1941–42 Harvard had a faculty of 2,098, a student body of 7,243, and a library of 2,236,146 volumes.

[10]See particularly: B. C. Steiner, *The History of Education in Connecticut* (Contributions, ed. H. B. Adams, No. 14), Washington, 1893, pp. 67–236; Ebenezer Baldwin, *Annals of Yale College*, 3d ed., New Haven, 1838; *Yale College, A Sketch of Its History*, ed. W. L. Kingsley, 2 vols., New

York, 1879; F. B. Dexter, *Biographical Sketches of the Graduates of Yale College with Annals of the College History* (cited hereinafter as "*Yale Graduates*"), 6 vols., New York and New Haven, 1885–1912; and *Historical Register of Yale University, 1801–1937*, New Haven, 1939. In 1941–42 Yale had a faculty of 575, a student body of 5,200, and a library of 3,074,817 volumes.

[11]See: H. B. Adams, *The College of William and Mary: a Contribution to the History of Higher Education, with Suggestions for Its National Promotion* (Contributions, ed. H. B. Adams, No. 1), Washington, 1887; L. G. Tyler, *The College of William and Mary in Virginia: Its History and Work, 1693–1907*, Richmond, 1907; G. W. Ewing, "Early Teaching of Science at the College of William and Mary in Virginia," *Bulletin of the College of William and Mary*, XXXII, No. 4, April, 1938. In 1941–42 William and Mary had a faculty of 110, a student body of 1,330, and a library of 170,000 volumes.

[12]See John DeWitt, "Princeton University," in Murray, *Hist. Ed. in N. J.*, pp. 199–286, and V. L. Collins, *Princeton* (American College and University Series), New York, 1914. In 1941–42 Princeton had a faculty of 391, a student body of 2,701, and a library of 985,000 volumes.

[13]See: F. R. Hathaway, "Columbia University," in Sidney Sherwood, *The University of the State of New York: History of Higher Education in the State of New York* (Contributions, ed. H. B. Adams, No. 28), Washington, 1900, pp. 133–98; *A History of Columbia University, 1754–1904*, New York, 1904; *Catalogue of Officers and Graduates of Columbia University from the Foundation of King's College in 1754*, New York, 1906; and F. P. Keppel, *Columbia* (American College and University Series), New York, 1914. In 1941–42 Columbia had a faculty of 3,096, a student body of 27,324, and a library of 1,887,034 volumes.

[14]See: F. N. Thorpe, *Benjamin Franklin and the University of Pennsylvania* (Bureau of Education, Circular of Information No. 2, 1892), Washington, 1893; T. H. Montgomery, *A History of the University of Pennsylvania from Its Foundation to A. D. 1770*, Philadelphia, 1900; and E. P. Cheyney, *History of the University of Pennsylvania*, 1740–1940, Philadelphia, 1940. In 1941–42 Pennsylvania had a faculty of 1,637, a student body of 12,736, and a library of 958,523 volumes.

[15]See: W. H. Tolman, *History of Higher Education in Rhode Island* (Contributions, ed. H. B. Adams, No. 18), Washington, 1894, pp. 93–200; R. A. Gould, *History of Brown University with Illustrative Documents*, Providence, 1867, and W. C. Bronson, *The History of Brown University*,

1764–1914, Providence, 1914. In 1941–42 Brown had a faculty of 230, a student body of 2,223, and a library of 603,000 volumes.

[16]See G. G. Bush, *History of Education in New Hampshire* (Contributions, ed. H. B. Adams, No. 22), Washington, 1898, pp. 137–70, and L. B. Richardson, *History of Dartmouth College*, 2 vols., Hanover, 1932. In 1941–42 Dartmouth had a faculty of 273, a student body of 2,426, and a library of 527,801 volumes.

[17]See Rowland Watts, "Washington College," in Steiner, *Hist. Ed. in Md.*, pp. 71–95, and H. W. Smith, *Life and Correspondence of the Rev. William Smith, D. D.*, Philadelphia, 1880, II, 65–90. In 1941–42 Washington had a faculty of thirty, a student body of 343, and a library of 25,000 volumes.

[18]See C. R. McIlwaine, "Hampden-Sidney College," in H. B. Adams, *Thomas Jefferson and the University of Virginia* (Contributions, ed. H. B. Adams, No. 2), Washington, 1888, pp. 227–39. In 1941–42 Hampden-Sidney had a faculty of twenty-one, a student body of 384, and a library of 20,000 volumes.

[19]See B. C. Steiner, "St. John's College," in *Hist. Ed. in Md.*, pp. 95–117. In 1941–42 St. John's had a faculty of twenty-nine, a student body of 184, and a library of 39,071 volumes.

[20]See E. B. Parsons, "Williams College," in Bush, *Hist. Higher Ed. in Mass.*, pp. 225–35, and L. W. Spring, *A History of Williams College*, Boston, 1917. In 1941–42 Williams had a faculty of ninety-eight, a student body of 869, and a library of 183,147 volumes.

[21]See L. S. Merriam, *Higher Education in Tennessee* (Contributions, ed. H. B. Adams, No. 16), Washington, 1893, pp. 229–31, and the current catalog of Tusculum, which has a brief paragraph on the college history. In 1941–42 Tusculum had a faculty of twenty-three, a student body of 315, and a library of 17,358 volumes.

[22]See C. L. Smith, *The History of Education in North Carolina* (Contributions, ed. H. B. Adams, No. 3), Washington, 1888, pp. 52–100, and K. P. Battle, *History of the University of North Carolina*, 2 vols., Raleigh, 1907–12. In 1941–42 North Carolina had a faculty of 300, a student body of 4,395, and a library of 419,797 volumes.

[23]See R. C. Alexander, "Union College," in Sherwood, *Univ. of the State of N. Y.*, pp. 198–228. In 1941–42 Union had a faculty of seventy-five, a student body of 776, and a library of 112,000 volumes.

[24]See A. F. Lewis, *History of Higher Education in Kentucky* (Contributions, ed. H. B. Adams, No. 25), Washington, 1899, pp. 35–82, and Robert and Johanna Peter, *Transylvania University* (Filson Club Publications, No. 11), Louisville, 1896.

III. ENTRANCE REQUIREMENTS

[1]The standard study is E. C. Broome, *A Historical and Critical Study of College Admission Requirements* (Columbia University Contributions to Philosophy, Psychology and Education, XI, Nos. 3–4), New York, April, 1903.

[2]Morison, *Founding of Harvard Coll.*, p. 333.

[3]Morison, *Harvard Coll. in the Seventeenth Century*, p. 81.

[4]Dexter, *Yale Graduates*, I, 347.

[5]*William and Mary College Quarterly Historical Magazine*, 1st series, XXII, 289, April, 1914. This periodical is cited hereinafter as "WMQ."

[6]Dexter, *Yale Graduates*, II, 2.

[7]Collins, *Princeton*, pp. 293–4.

[8]*Hist. Columbia Univ.*, p. 443.

[9]Tyler, *Coll. of Wm. and Mary*, p. 53.

[10]Ewing, *Early Teaching of Science at Wm. and Mary*, p. 11.

[11]See *The Complete Jefferson*, ed. S. K. Padover, New York, 1943, pp. 1150–51.

[12]See Florian Cajori, *The Teaching and History of Mathematics in the United States* (Bureau of Education, Circular of Information No. 3, 1890), Washington, 1890, p. 60, and Miller, *Brief Retrospect*, II, 499.

[13]See Bush, *Hist. Higher. Ed. in Mass.*, p. 226.

[14]See Smith, *Hist. Ed. in N. C.*, p. 63.

[15]See Miller, *Brief Retrospect*, II, 499, and Bronson, *Hist. Brown Univ.*, pp. 101–2.

[16]L. P. Powell, *The History of Education in Delaware* (Contributions, ed. H. B. Adams, No. 15), Washington, 1893, p. 46.

[17]See C. E. Cuningham, *Timothy Dwight, 1752–1817: a Biography*, New York, 1943, p. 144.

[18]See Easterby, *Hist. Coll. of Charleston*, pp. 37, 267.

[19]*The History of New Hampshire*, III, Boston, 1792, 290.

IV. THE CURRICULUM

[1]This table is based upon the chart printed in Morison, *Harvard Coll. in the Seventeenth Century*, p. 141. The computation is mine—Dunster, if he

could see it, would doubtless be horrified at the reduction of a gentleman's education to so many credit hours.

[2]*Ibid.*, p. 145.

[3]*Ibid.*, pp. 146–7.

[4]*Ibid.*, p. 208.

[5]See Cajori, *Teaching and Hist. of Math.*, p. 58.

[6]See Tyler, *Coll. of Wm. and Mary*, p. 88, and *The Official Letters of Alexander Spotswood*, ed. R. A. Brock, I, Richmond, 1882, 103, 156–8.

[7]Tyler says (*Coll. of Wm. and Mary*, p. 22) that the Rev. James Fontaine was offered the chair in 1716, but did not accept. Dates of birth and death given in the text and followed by an asterisk indicate that the individual named is in the *Dictionary of American Biography*, which is, of course, a vast storehouse of information relating to the subject of the present monograph.

[8]See Tyler, *Coll. of Wm. and Mary*, pp. 27–9, and *WMQ*, 1st series, XVI, 248, April, 1908.

[9]*WMQ*, 1st series, XXII, 289, April, 1914. The statutes were adopted in 1727 and first printed at Williamsburg in 1736.

[10]See Morison, *Three Centuries of Harvard*, p. 79.

[11]See L. G. Simons, "Isaac Greenwood, First Hollis Professor," *Scripta Mathematica*, II, 117–24, February, 1934.

[12]See Quincy, *Hist. Harvard Univ.*, II, 17.

[13]See Morison, *Three Centuries of Harvard*, p. 80.

[14]See: L. G. Simons, "Isaac Greenwood's Arithmetic," *Scripta Mathematica*, I, 262–4, March, 1933; L. G. Karpinski, *Bibliography of Mathematical Works Printed in America before 1850*, Ann Arbor, 1940; and L. G. Simons, *Introduction of Algebra into American Schools in the Eighteenth Century* (Bureau of Education Bulletin, 1924, No. 18), Washington, 1924, pp. 3–17.

[15]See Dexter, *Yale Graduates*, II, 5–6.

[16]See: Collins, *Princeton*, pp. 298–304; Bronson, *Hist. Brown Univ.*, pp. 103, 166–7; Smith, *Hist. Ed. in N. C.*, p. 63; Richardson; *Hist. Dartmouth Coll.*, I, 119; and Miller, *Brief Retrospect*, II, 496.

[17]This table is based upon the outline printed in Smith, *Life and Correspondence of the Rev. William Smith*, I, 58–9. The computation is mine.

[18]See: L. F. Snow, *The College Curriculum in the United States* (Columbia University Contributions to Education, Teachers College Series, No. 10), New York, 1907, pp. 17–18; Montgomery, *Hist. Univ. of Pa.*, pp. 234–43; Cheyney, *Hist. Univ. of Pa.*, p. 82; Theodore Hornberger, "A

Note on the Possible Source of Provost Smith's Famous Curriculum for the College of Philadelphia," *Pennsylvania Magazine of History*, LVIII, 370–76, October, 1934; and A. F. Gegenheimer, *William Smith*, Philadelphia, 1943.

[19]See Steiner, *Hist. Ed. in Md.*, p. 79.

[20]*Hist. Columbia Univ.*, pp. 444–5.

[21]*Ibid.*, p. 449.

[22]*Ibid.*, p. 450.

[23]*Catalogue of Officers and Graduates of Columbia Univ.*, pp. 24–5.

[24]See Miller, *Brief Retrospect*, II, 499.

[25]*Idem.* The paragraphing is mine.

[26]*WMQ*, 1st series, XX, 58, July, 1911.

V. TEACHERS, METHODS, AND TEXTBOOKS

[1]Morison, *Harvard Coll. in the Seventeenth Century*, p. 645.

[2]See Morison, *Founding of Harvard Coll.*, p. 138.

[3]Morison, *Harvard Coll. in the Seventeenth Century*, p. 235. See also W. M. Smallwood, *Natural History and the American Mind*, New York, 1941, pp. 42–4.

[4]The extant Harvard theses are printed in Morison, *Harvard Coll. in the Seventeenth Century*, pp. 580–631. See also: W. C. Lane, "Early Harvard Broadsides," *Proceedings of the American Antiquarian Society*, new series, XXIV, 1914, 264–304; and Gould, *Hist. Brown Univ.*, pp. 343–68.

[5]Morison, *Harvard Coll. in the Seventeenth Century*, p. 216.

[6]See S. E. Morison, "The Harvard School of Astronomy in the Seventeenth Century," *New England Quarterly*, VII, 3–24, March, 1934.

[7]Morison, *Harvard Coll. in the Seventeenth Century*, p. 214.

[8]*Ibid.*, pp. 220–21. See also Florian Cajori, *The Early Mathematical Sciences in North and South America*, Boston, 1928, p. 42.

[9]See Morison, *Harvard Coll. in the Seventeenth Century*, pp. 223–51, and J. J. McCarthy, "Physics in American Colleges before 1750," *American Physics Teacher*, VII, 100–104, April, 1939.

[10]See Morison, *Harvard Coll. in the Seventeenth Century*, p. 233.

[11]*Publications of the Colonial Society of Massachusetts*, XXXIII, 1940. Since the publication of the list on pp. xxxiii–xxxv, an additional transcription has been found at the Massachusetts Historical Society. It is greatly abbreviated, having only thirty-four pages and no diagrams, and was probably made by Richard Waldron of the Harvard class of 1712. For this information I am indebted to Mr. Allyn B. Forbes.

[12]Simons, *Introduction of Algebra,* p. 47.

[13]*Ibid.,* p. 48.

[14]See Tyler, *Coll. of Wm. and Mary,* p. 88.

[15]See Snow, *Coll. Curriculum in the U. S.,* p. 91, and Morison, *Harvard Coll. in the Seventeenth Century,* p. 155, note.

[16]See Snow, *Coll. Curriculum in the U. S.,* pp. 90–91, and T. D. Woolsey, "The Course of Instruction in Yale College," in *Yale College,* ed. W. L. Kingsley, II, 499–500.

[17]See Christopher Wordsworth, *Scholae Academicae,* Cambridge, Eng., 1910, pp. 13, 67, 132, 298, 336.

[18]The works of Le Clerc are listed in Robert Watt, *Bibliotheca Britannica,* Edinburgh, 1824.

[19]*Samuel Johnson, President of King's College: His Career and Writings,* ed. Herbert and Carol Schneider, New York, 1929, II, 55–186.

[20]See: Louis Shores, *Origins of the American College Library,* 1638–1800, Nashville, 1934, pp. 75–8, Anne S. Pratt, "The Books Sent from England by Jeremiah Dummer to Yale College," in *Papers in Honor of Andrew Keogh,* New Haven, 1938, pp. 7–44; and the analysis of the list by Louise May Bryant and Mary Patterson, *ibid.,* pp. 423–92.

[21]F. E. Brasch has recently demonstrated that James Logan of Pennsylvania acquired a copy of the *Principia* in 1708. See "James Logan, a Colonial Mathematical Scholar, and the First Copy of Newton's Principia to Arrive in the Colony," *Proceedings of the American Philosophical Society,* LXXXVI, 1943, 6. It is hard to believe that Thomas Brattle did not acquire a copy of Newton's book.

[22]See Simons, *Introduction of Algebra,* pp. 32–5.

[23]See F. G. Kilgour, "Thomas Robie (1689–1729), Colonial Scientist and Physician," *Isis,* XXX, 473–90, August, 1939.

[24]See L. G. Simons, "The Adoption of the Method of Fluxions in American Schools," *Scripta Mathematica,* IV, 207, July, 1936, and *Introduction of Algebra,* pp. 37–8.

[25]See *Pub. Col. Soc. Mass.,* XXXIII, xxxv, and L. G. Simons, "Short Stories in Colonial Geometry," *Osiris,* I, 588, January, 1936. Cf. also *Introduction of Algebra,* p. 3.

[26]Simons, *Introduction of Algebra,* p. 45.

[27]See L. C. Karpinski, *The History of Arithmetic,* Chicago, 1925, pp. 81–2, 116–19, 134–5, 140–41, 149–50, and D. E. Smith and Jekuthiel Ginsburg, *A History of Mathematics in America before 1800* (The Carus Mathematical Monographs, No. 5), Chicago, 1934, pp. 39–40.

[28]See Simons, *Introduction of Algebra*, pp. 3–17.

[29]*Ibid.*, p. 68.

[30]See *Explanatory Lectures on the Orrery, Armillary Sphere, Globes and Other Machines, Instruments and Schemes Made Use of by Astronomers: Accompanied with a Great Variety of Physical Experiments and Curious Remarks*, Boston, 1734.

[31]The chief authority on Winthrop is F. E. Brasch, long Chief of the Smithsonian Division, Library of Congress, to whom I am indebted for many courtesies. Mr. Brasch is preparing a full-length biography; he is also the author of "John Winthrop" in *Publications of the Astronomical Society of the Pacific*, No. 165, XXVIII, 153–70, August–October, 1916, and of "Newton's First Critical Disciple in the American Colonies—John Winthrop," in *Sir Isaac Newton, 1727–1927, a Bicentenary Evaluation of His Work*, Baltimore, 1928, pp. 301–38.

[32]The best account of Clap (1703–67*) is still F. B. Dexter, "Thomas Clap and His Writings," *Papers of the New Haven Colony Historical Society*, V, 1894, 247–74.

[33]See Simons, in *Scripta Mathematica*, IV, 208–10, July, 1936, and *Introduction of Algebra*, pp. 38–40. It would seem that the theses on fluxions at Harvard in 1719 probably do not mean that they were actually studied at that date. See Cajori, *Teaching and Hist. of Math.*, p. 27, and F. E. Brasch's review of Smith and Ginsburg, *Hist. Math. in America before 1900*, in *Isis*, XXII, 555, February, 1935.

[34]For analysis, see Cajori, *Teaching and Hist. of Math.*, p. 27. Karpinski, *Hist. of Arithmetic*, p. 74, reprints the title-page of the first edition.

[35]See: Smith and Ginsburg, *Hist. of Math. in America before 1900*, p. 40; *The Literary Diary of Ezra Stiles*, ed. F. B. Dexter, New York, 1901, II, 388, III, 312; Montgomery, *Hist. Univ. of Pa.*, pp. 238, 257; Belknap, *Hist. of N. H.*, III, 296; and Cajori, *Teaching and Hist. of Math.*, pp. 24–5.

[36]Winthrop's books are now in the library of Allegheny College. I am indebted to Mr. Brasch for a list of them. See also *Sir Isaac Newton*, p. 316.

[37]Edward Wigglesworth, *The Hope of Immortality*, Boston, 1779, appendix, p. i. The "Gentleman" was almost certainly Ezra Stiles. Soon after Winthrop's death, he wrote in his diary concerning Myles Cooper, president of King's College, as possessing "a very slight Insight into math. & nat. Phil. & Astronomy, not anything beyond what is taught to boys, petit Maitres & Ladies—& level to the Capacities of those who have learned only the Elements of Arith. Algebra and Geometry." (*Literary Diary*, II, 339.)

[38]*Ibid.*, p. 334.

[39]See Dexter, *Yale Graduates*, II, 383–8, IV, 43–7. Stiles, *Literary Diary, passim*, gives many details of their lectures and their discontent.

[40]HU 723.215.6. A notation indicates that it was read May 10, 1780, and again, as two lectures, on August 25 and September 8, 1784, and August 23, and 30, 1786. For Williams (1743–1817) see W. B. Sprague, *Annals of the American Pulpit*, I, New York, 1857, 595–7. Professor Merle Curti, of the University of Wisconsin, is engaged upon a new study of Williams, based upon manuscripts at the Vermont State Historical Society.

[41]For Webber (1759–1810) see *Appleton's Cyclopaedia of American Biography*, VI, New York, 1894, 405, and Cajori, *Teaching and Hist. of Math.*, pp. 60–61.

[42]For Woodward (1745–1804) see Dexter, *Yale Graduates*, III, 89–92, and Richardson, *Hist. Dartmouth Coll.*, I, 101, 128, 198, 203, 251.

[43]See Belknap, *Hist. of N. H.*, III, 296.

[44]See Cajori, *Teaching and Hist. of Math.*, pp. 33–6.

[45]See Simons, in *Scripta Mathematica*, IV, 211, July, 1936.

[46]Howell was also professor of law from 1790 to 1824, although he never lectured.

[47]See Bronson, *Hist. Brown Univ.*, pp. 155, 195, 200.

[48]*Ibid.*, pp. 102–3. The identifications, which are of course tentative, are here, as elsewhere, based upon Watt, *Bibliotheca Britannica*, and the catalog of printed books in the British Museum.

[49]*Catalogue of Officers and Graduates of Columbia Univ.*, p. 63. There is no good account of Treadwell; for brief notes see: Joseph Lovering, "Boston and Science," in *The Memorial History of Boston*, ed. Justin Winsor, IV, Boston, 1881, 498; Marcus Benjamin, "The Development of Science in New York City," in *The Memorial History of the City of New York*, ed. J. G. Wilson, IV, New York, 1893, 414; and Smallwood, *Nat. Hist. and the American Mind*, pp. 288–9.

[50]James Renwick, *Life of Dewitt Clinton*, New York, 1859, pp. 32–3.

[51]See Montgomery, *Hist. Univ. of Pa.*, pp. 236–9.

[52]See Cheyney, *Hist. Univ. of Pa.*, p. 79, and Smith, *Life and Correspondence of the Rev. William Smith*, I, 58. Grew was the author of *The Description and Use of the Globes*, Germantown, 1753, which has an appendix called by L. C. Karpinski "the first trigonometric treatise of the Americas" (*Bibliography of Mathematical Works Printed in America before 1850*, p. 63).

[53]See: Cajori, *Teaching and Hist. of Math.*, pp. 65–6; Simons, *Introduction of Algebra*, pp. 21–6; and Smith and Ginsburg, *Hist. Math. in America before 1900*, pp. 31–2.

[54]See Collins, *Princeton*, p. 70.

[55]See Simons, *Introduction of Algebra*, pp. 18–20.

[56]*An Inaugural Oration*, pp. 30–37.

[57]Quincy, *Hist. Harvard Univ.*, II, 532–3. The quotation comes from a letter written by Winthrop to the chairman of a committee of the Massachusetts House of Representatives, in answer to a request for an account of his services and perquisites.

[58]HU 723.251.15. It consists of thirty-three lectures, delivered between March 10 and June 16.

[59]Quincy, *Hist. Harvard Univ.*, II, 482–3.

[60]Morison, *Three Centuries of Harvard*, p. 92.

[61]See F. G. Kilgour, "Professor John Winthrop's Notes on Sun Spot Observations (1739)," *Isis*, XXIX, 355–61, November, 1938.

[62]See *A Lecture on Earthquakes*, Boston, 1755, pp. 10–11, and cf. A. Wolf, *A History of Science, Technology, and Philosophy in the Eighteenth Century*, New York, 1939, p. 398.

[63]See: *The Boston News-Letter*, April 2, April 30, and July 30, 1761; *Relation of a Voyage from Boston to New Foundland for the Observation of the Transit of Venus, June 6, 1761*, Boston, 1761; *Two Lectures on the Parallax and Distance of the Sun, as Deducible from the Transit of Venus*, Boston, 1769; and the *Philosophical Transactions*, LIV, 1764, 279–83.

[64]See *Collections of the Massachusetts Historical Society*, 5th series, IV, 291–313.

[65]See Snow, *Coll. Curriculum in the U. S.*, pp. 47–8. The books may be identified as follows: Isaac Watts, *The Knowledge of the Heavens and Earth Made Easy* (London, 1726, 3d ed., 1736; 8th ed., 1772); Patrick Gordon, *Geography Anatomiz'd: or a Compleat Geographical Grammar* (London, 1693; 16th ed., 1740; 20th ed., 1754); Willem Jakob van 's Gravesande, *Physicos Elementa Mathematica* (Leyden, 1720; trans. by J. T. Desaguliers as *Mathematical Elements of Natural Philosophy, Confirmed by Experiments, or an Introduction to Sir Isaac Newton's Philosophy*, London, 1721; 5th ed., 1737).

[66]See Woolsey, in *Yale Coll.*, ed. W. L. Kingsley, II, 500.

[67]See: Snow, *Coll. Curriculum in the U. S.*, p. 91; Bronson, *Hist. Brown Univ.*, pp. 102–3; Belknap, *Hist. of N. H.*, III, 296. *The Philosophical Grammar; Being a View of the Present State of Experimental Physiology, or Natural Philosophy* was first published at London in 1735. Martin later wrote a three-volume *Philosophia Britannica; or, a Complete System of the Newtonian Philosophy* (London, 1759), which was also used as a textbook in American colleges.

[68]See Snow, *Coll. Curriculum in the U. S.*, p. 90, and Miller, *Brief Retrospect*, II, 494. Enfield was being used at Dartmouth in 1792 (Belknap, *Hist. of N. H.*, III, 296) and at Brown as late as 1823 (Bronson, *Hist. Brown Univ.*, p. 167).

[69]See Quincy, *Hist. Harvard Univ.*, II, 483–93.

[70]See Tyler, *Coll. of Wm. and Mary*, p. 41. For Small (1734–75) see J. G. Crowther, *Famous American Men of Science*, New York, 1937, pp. 30–33, and L. C. Tyler, "Virginia's Contribution to Science," *Proc. Amer. Antiq. Soc.*, new series, XXV, 1915, 363–4.

[71]*The Complete Jefferson*, p. 1120.

[72]So says Ewing, *Early Teaching of Science at Wm. and Mary*, pp. 6–7.

[73]Printed *ibid.*, pp. 7–9.

[74]*Ibid.*, p. 13.

[75]*Hist. Columbia Univ.*, p. 78.

[76]See Collins, *Princeton*, p. 297, and L. H. Gipson, *Lewis Evans*, Philadelphia, 1939, pp. 8–10.

[77]Collins, *Princeton*, p. 55.

[78]*Ibid.*, p. 105.

[79]See Montgomery, *Hist. Univ. of Pa.*, p. 237.

[80]See Cheyney, *Hist. Univ. of Pa.*, pp. 44–5.

[81]*Ibid.*, p. 132. For Ewing see Lucy E. Lee Ewing, *Dr. John Ewing and Some of His Noted Connections*, Philadelphia, 1924.

[82]See Cheyney, *Hist. Univ. of Pa.*, p. 133.

[83]See, for example, *Life, Journals and Correspondence of Rev. Manasseh Cutler*, ed. W. P. and Julia P. Cutler, Cincinnati, 1888, I, 264. Cutler found the university library "very small, consisting only of a few antiquated authors, and the apparatus not much better," but remarked that these things were "pretty well supplied" by other institutions in the city.

[84]See Bronson, *Hist. Brown Univ.*, p. 81.

[85]*Ibid.*, pp. 106–8, 146, and H. M. Fuller, "The Philosophical Apparatus of Yale College," in *Papers in Honor of Andrew Keogh*, pp. 163–80.

[86]See Smith, *Hist. Ed. in N. C.*, p. 61.

[87]See Dexter, Yale Graduates, I, 754, and Chauncey Whittlesey's description in the *American Magazine*, January, 1744.

[88]*The Complete Jefferson*, p. 611.

[89]See James Stokley, "The Rittenhouse Exhibition," *Pa. Mag. Hist.*, LVI, 236–48, July, 1932, and Collins, *Princeton*, p. 74.

[90]See H. E. Keyes, "Harvard Has an Orrery," *Antiques*, XXXI, 113–15, March, 1937.

[91]See Smallwood, *Natural Hist. and the American Mind*, pp. 288–9.

[92]*Ibid.*, p. 324, and Cheyney, *Hist. Univ. of Pa.*, pp. 101–2.

[93]Smallwood, *Natural Hist. and the American Mind*, pp. 290–93.

[94]See *The Complete Jefferson*, pp. 1150–51.

[95]See Bronson, *Hist. Brown Univ.*, pp. 81, 267.

[96]See: *The Monthly Anthology*, I, 308–12, May, 1804; *Heads of a Course of Lectures on Natural History*, Cambridge, 1810; *The Botanist*, Boston, 1811.

[97]See *Hist. Columbia Univ.*, p. 64, and *Catalogue of Officers and Graduates of Columbia Univ.*, p. 53. There seems to be no good account of Moyes. A Scot, educated at Glasgow and Edinburgh, although handicapped by blindness, he was apparently chiefly interested in physics and chemistry. See Stiles, *Literary Diary*, III, 190.

[98]See *Hist. Columbia Univ.*, p. 76. For Mitchill see C. R. Hall, *A Scientist in the Early Republic*, New York, 1934.

[99]See *Natural Hist. and the American Mind*, pp. 297–301.

[100]*Life, Journals and Correspondence*, I, 220.

[101]Individual students perhaps studied chemistry privately, as did George Starkey of the Harvard class of 1646. See Morison, *Harvard Coll. in the Seventeenth Century*, p. 235.

[102]See E. F. Smith, *Old Chemistries*, New York, 1927, pp. 9–10.

[103]See *Catalogue of Officers and Graduates of Columbia Univ.*, pp. 29, 52–3, 60.

[104]See J. B. Langstaff, *Doctor Bard of Hyde Park*, New York, 1942.

[105]See Cheyney, *Hist. Univ. of Pa.*, pp. 102, 156, 213.

[106]See Smith, *Old Chemistries*, pp. 12–13, for extracts from Rush's syllabus; E. F. Smith, *Chemistry in America*, *New York*, 1914, pp. 76–9, for a description of the Woodhouse book.

[107]See Collins, *Princeton*, p. 101.

[108]An outline of the notebook is given by William Foster, in "John Maclean—Chemist," *Science*, LX, 306–8, October 3, 1924.

[109]See Smallwood, *Natural Hist. and the American Mind*, p. 331.

[110]See C. R. Dryer, "A Century of Geographic Education in the United States," *Annals of the Association of American Geographers*, XIV, No. 33, September, 1924, p. 130.

[111]See *Catalogue of Officers and Graduates of Columbia Univ.*, pp. 41, 46, 71.

[112]See Collins, *Princeton*, p. 297.

[113]See Snow, *Coll. Curriculum in the U. S.*, pp. 91–109, and Belknap, *Hist. of N. H.*, III, 296.

[114]See J. K. Morse, *Jedidiah Morse, a Champion of New England Orthodoxy*, New York, 1939.

VI. LIBRARIES

[1]See "The First Century of Scientific Books in the Harvard College Library," *Harvard Library Notes*, III, No. 29, 217–25, March, 1939.

[2]*Idem.*

[3]*Manuductio ad Ministerium*, pp. 47–50.

[4]See *Samuel Johnson: His Career and Writings*, II, 317–20.

[5]See Shore, *Origins of the American Coll. Library*, pp. 31–2.

VII. THE EFFECTS

[1]See: K. B. Murdock, *Increase Mather, the Foremost American Puritan*, Cambridge, 1925, pp. 147–8; *Selections from Cotton Mather*, ed. K. B. Murdock, New York, 1926, pp. xlviii-li, lvi-lviii; and two studies by Theodore Hornberger: "The Date, the Source, and the Significance of Cotton Mather's Interest in Science," *American Literature*, VI, 413–20, January, 1935; and "Notes on *The Christian Philosopher*," in T. J. Holmes, *Cotton Mather, a Bibliography of His Works*, Cambridge, 1940, I, 133–8.

[2]The chief point to the contrary is an objection in Samuel Sewall's diary to a sermon in which Cotton Mather mentioned the sun as the center of our system, in 1714. Though this statement is slight in comparison to what has been shown to have been taught at Harvard, J. T. Adams has remarked (*Provincial Society, 1690–1763*, New York, 1928, p. 124) that "Sewall's was probably the more widely held opinion."

[3]Cotton Mather, *Parentator*, quoted in Murdock, *Increase Mather*, p. 148.

[4]*The Christian Philosopher*, p. 1.

[5]See, for Dell (d. 1664), the article by J. Bass Mullinger in the *Dictionary of National Biography*.

[6]*Gods Mercy Shewed to His People in Giving Them a Faithful Ministry and Schools of Learning for the Continual Supplyes Therof*, Cambridge, 1655, p. 35.

[7]*Ibid.*, p. 37.

[8]See, for example, Increase Mather, *A Discourse Proving That the Christian Religion Is the Only True Religion*, Boston, 1702, and Cotton

Mather, *Reasonable Religion,* Boston, 1700, and *Reason Satisfied; and Faith Established,* Boston, 1712.

[9]See also Williston Walker, *Ten New England Leaders,* New York, 1901, pp. 265–310.

[10]*The Benevolence of the Deity, Fairly and Impartially Considered,* Boston, 1784, pp. 60–61.

[11]See Theodore Hornberger, "Samuel Johnson of Yale and King's College: a Note on the Relation of Science and Religion in Provincial America," *New England Quarterly,* VIII, 378–97, September, 1935.

[12]See Theodore Hornberger, "The Effect of the New Science upon the Thought of Jonathan Edwards," *American Literature,* IX, 196–207, May, 1937.

[13]*A Compleat Body of Divinity,* Boston, 1726, p. iii.

[14]*The Lord Jesus Christ, the Only and Supreme Head of the Church,* Boston, 1738, p. 28.

[15]*Some Seasonable Thoughts on Evangelic Preaching,* Boston, 1740, title-page.

[16]*Poems of Freneau,* ed. H. H. Clark, New York, 1929, pp. 423–4.

[17]See Crowther, *Famous American Men of Science,* pp. 135–54.

[18]*Discourse on Natural Religion,* Boston, 1799, p. 24. There is a brief account of Mellen (1743?–1828) in Sprague, *Annals of the American Pulpit,* II, 450.

[19]*An Oration,* Providence, 1798, pp. 7–8.

Index

Aberdeen University, 54
Academia Secretorum Naturae, 3
Adams, George, 64
Adams, John, 85, 86
Adams, John Quincy, 85
Agriculture, 29, 30, 31, 33, 35, 65, 71
Allegheny College, 60
American Academy of Arts and Sciences, 67
American Philosophical Society, 66
Apparatus, 5, 7, 8, 9, 10, 11, 12, 13, 14, 40, 45–7, 58–9, 61, 62, 65, 66, 67; air-pumps, 47, 59, 65, 67; barometers, 59, 61, 62, 67; electrical machines, 62, 67; globes, 47, 61, 67, 74; microscopes, 59, 61, 62, 65, 67; orreries, 47, 61, 67–8; telescopes, 12, 35, 39, 48, 61, 62, 65, 67; thermometers, 67, 69
Aristotle, 26, 39, 40, 84
Astronomy, 14, 18, 20, 21, 23, 24, 27, 28, 29, 30, 32, 33, 35, 36, 38–9, 44, 47, 48, 51, 53, *57–69*, 81

Bard, Samuel, 72
Barlow, Joel, 85
Barnard, John, 83, 84
Barrow, Isaac, 51, 56
Barton, Benjamin Smith, 70, 71
Beaufort, S. C., college at, 6
Belcher, Jonathan, 76
Berkeley, George, 82
Boerhaave, Hermann, 66
Botany. See *Natural History*.
Bowdoin College, 5, 6, 89
Boyle, Robert, 35, 39, 40
Brackenridge, Hugh Henry, 85
Brahe, Tycho, 47
Brattle, Thomas, 39, 44
Brigden, Zecheriah, 38
Brown, Joseph, 66
Brown University (Rhode-Island College), 5, 10, 14, 20, 28, 36, 50, 52, 53, 66–7, 70, 75, 78, 87–8, 91–2
Brownwell, George, 17, 18
Burnet, Thomas, 77

Cambridge, S. C., college at, 6
Cambridge University, 3, 81
Cavallo, Tiberius, 64
Channing, William Ellery, 85
Chaptal, Jean Antoine Claude, 64
Charleston, College of, 6, 7, 20–21, 74, 90
Chauncy, Charles (1592–1672), 81
Chauncy, Charles (1705–87), 82
Cheever, Samuel, 38
Chemical Society of Philadelphia, 73
Chemistry, 7, 8, 9, 10, 11, 14, 21, 28, 29, 31, 32, 35, 48, 62–4, 66, 69, 71, *72–4*
Clap, Thomas, 40, 44, 49, 57, 60, 67, 77, 86
Clarke, Samuel, 42
Clinton, De Witt, 54, 85
Cokesbury College, 6
Colson, John, 64
Columbia University (King's College, Columbia College), 6, 9, 10, 14, 18–19, 28, 30–33, 42, 52, 53–4, 65, 69, 71, 72, 75, 77, 78, 85, 91
Cooper, Myles, 54
Copernicus, 38, 47
Cowley, Abraham, 68
Crowther, J. G., 86
Cullen, William, 72
Cutler, Manasseh, 71–2
Cutler, Timothy, 43

Dartmouth College, 5, 11, 14, 20, 28, 50, 52, 75, 78, 92
Davies, Samuel, 65
Dell, William, 81
Derham, William, 77
Desaguliers, J. T., 45, 46, 57, 58, 60, 63, 64, 66
Descartes, René, 39, 40, 51, 84
Dexter, Andrew, Jr., 87
Dickinson College, 6, 78, 90
Disputations, 23, 24, 29, 33, 36, 40
Divinity, 7, 8, 23, 24, 26, 28, 81, 84
Dove, James David, 65
Dummer, Jeremiah, 43, 76

Dunster, Henry, 22, 23, 25, 33, 37, 38, 39, 69
Dwight, Timothy, 20

Edwards, Jonathan, 82–3
Einstein, Albert, 57
Elam, Samuel, 10
Enfield, William, 60
Evans, Lewis, 65
Ewing, John, 66, 72

Fauquier, Francis, 61
Fenning, Daniel, 53
Ferguson, James, 60
Flamsteed, John, 39
Foxcroft, Thomas, 83, 84
Franklin, Benjamin, 2, 10, 17, 20
Franklin and Marshall College (Franklin College), 6, 90
Freneau, Philip, 85, 86
Fry, Joshua, 41

Galileo, 38
Geography, 9, 14, 20, 21, 24, 27, 28, 30, 31, 32, 33, 47, 48, 54, 60, *74–5*, 77
Geology. See *Natural History*.
Georgetown University (Catholic College of Georgetown), 6, 90
Georgia, University of, 6, 7
Gordon, Patrick, 60, 65, 75
Gravesande, W. J.'s, 60, 66
Green, John, 18
Greenfield, Hill Academy, 20
Greenwood, Isaac, 26, 27, 44–8, 57, 651, 74, 83
Gregory, David, 55
Grew, Theophilus, 55
Gross, John Daniel, 75
Gunther, R. T., 3
Guthrie, William, 75

Halley, Edmund, 43
Hamilton, Alexander, 85
Hamilton, Robert, 54
Hammond, Nathaniel, 50, 52, 53
Hampden-Sidney College (Prince Edward Academy), 6, 11, 92
Harpur, Robert, 53
Harris, John, 55
Harvard University (Harvard College), 5, 7, 14, 16–17, 19, 22–5, 26–7, 28, 33, 35, 36, 37–41, 43, 44–8, 49, 50, 51–2, 57–61, 67–8, 74, 75, 76–7, 80–88, 83, 85, 87, 90
Hanksbee, Francis, 45
Helsham, Richard, 64, 66
Hill, John, 53
History, 23, 29, 30
Hoar, Leonard, 35
Hollis, Thomas, 26, 27, 49, 61
Hopkinson, Francis, 85
Houston, William Churchill, 56
Howell, David, 53
Hutchinson, James, 73
Hutchinson, John, 83

Irvine, Alexander, 41

Jay, John, 85
Jefferson, Thomas, 41, 52, 61, 67, 70, 85
Johnson, Samuel, 30, 31, 42, 43, 47, 53, 77, 82, 83
Jones, Hugh, 25, 41

Keill, John, 53, 65
Kemp, John, 54, 65, 66, 75
Kentucky, University of. See *Transylvania University*.
Kepler, John, 38
Kerr, Robert, 64
Kilgour, F. G., 76
Kuhn, Adam, 69

Languages, 8, 12; classical, 2, 8, 20, 21, 23, 24, 27, 33; Latin, 9, 10, 11, 13, 14, 16, 17, 18, 19, 23, 24, 25, 28, 29, 31, 32, 33; Greek, 9, 10, 11, 13, 14, 16, 17, 18, 19, 23, 24, 25, 28, 29, 31, 32; modern, 8, 33; French, 12, 19, 31; German, 31; oriental, 8, 10, 31; Aramaic, 23; Hebrew, 23, 24, 28; Syriac, 23
Laplace, Pierre Simon, 20
Lavoisier, Antoine Laurent, 64, 73
Law, 8, 10, 14, 31
Le Clerc, Jean, 42
Le Fevre, 25, 27, 41

Libraries, 5, 7, 8, 9, 10, 11, 12, 13, 14, *76–8*
Library Company of Philadelphia, 7
Linnæus, 3, 69
Locke, John, 84
Love, John, 53

MacLaurin, Colin, 55, 60, 66
Maclean, John, 71, 73
Madison, James (1759–1812), 19, 20, 62, 77
Madison, James (1751–1836), 85
Magirus, Johannes, 39, 52
Martin, Benjamin, 53, 60, 64, 66
Maryland, University of, See *St. John's College, Washington College.*
Masson, David, 79
Mathematics, 7, 8, 9, 10, 11, 12, 13, 14, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33–7, 41, 43, *49–57*, 65, 68, 69, 70, 77; arithmetic, 16, 17, 18, 19, 20, 23, 24, 25, 27, 28, 32, 41, 44, 47, 49, 52, 53, 55, 68; algebra, 20, 27, 32, 33, 41, 43, 47, 49, 50, 52, 53, 55, 68; geometry, 18, 20, 23, 24, 25, 27, 28, 32, 33, 38, 44, 47, 49, 50, 53, 54, 55, 57, 68; trigonometry, 18, 20, 32, 33, 47, 55, 55; conic sections, 20, 32, 33, 47, 49, 55; calculus (fluxions), 48, 49, 52, 53, 55, 56; navigation, 18, 20, 30, 32, 36, 41, 48, 53, 55; surveying, 30, 33, 38, 41–2, 53, 55, 56, 85
Mather, Cotton, 17, 77, 80, 82
Mather, Increase, 80, 82
Medical Science; anatomy, 7, 9, 10, 31, 69; materia medica, 7, 9, 10, 31, 69; medicine, theory and practice of (institutes of), 9, 10, 11, 14, 31, 72–3; midwifery, 31; obstetrics, 9; pathology, 31; physic, theory and practics of, 7, 70; physiology, 31, 69; surgery, 7, 9, 14, 17, 20, 31, 38, 48
Meigs, Josiah, 51
Mellen, John, 87
Michell, John, 59
Middlebury College, 5, 6, 90
Middleton, Peter, 72
Mineralogy. See *Natural History.*
Minto, Walter, 56–7
Mitchill, Samuel Latham, 71
Montgomery, Richard, 88
Morison, Samuel Eliot, 24, 37
Morse, Jedidiah, 75
Morton, Charles, 40, 44
Mount Zion Institute, 6
Moyes, Henry, 71
Musschenbroeck, Peter de, 66

Natural history, 10, 28, 29, 31, 48, 53, 65, 69–72, 74; botany, 9, 19, 23, 24, 30, 31, 33, 35, 37; geology and mineralogy, 30, 70; zoology, 30, 70
Natural philosophy, 7, 8, 9, 10, 11, 13, 14, 21, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 37, 38, 39–40, 42, 43, 44, 45–7, 48, 51, 52, 53, 54, *57–79*, 70, 72, 81, 86–7
Newton, Isaac, 3, 20, 26, 27, 39, 40, 42, 43, 45, 51, 56, 60
Nicoll, Samuel, 72
North Carolina, University of, 6, 13, 20, 28, 67, 92

Oratory, 7, 21, 24, 29; public speaking, 32
Oughtred, William, 51
Oxford University, 3

Patoun, Archibald, 55
Pardies, Ignace Gaston, 55
Patterson, Robert, 56, 66
Patoun, Archibald, 55
Pemberton, Henry, 60
Pennsylvania, University of (College of Philadelphia), 6, 9–10, 14, 22, 28–9, 50, 52, 55–6, 65–6, 67, 69–70, 72–3, 78, 85, 91
Phillips-Exeter Academy, 21
Philosophy; logic, 9, 10, 11, 14, 21, 23, 24, 26, 29, 30, 31, 33; ethics and moral philosophy, 8, 9, 10, 14, 23, 24, 26, 28, 29, 51, 81; politics and natural law, 23, 29, 30, 31, 33; metaphysics, 14, 24, 26, 27, 31. See also *Natural Philosophy.*
Physics. See *Natural Philosophy.*

Pierson, Abraham, 42
Pike, Nicholas, 49, 52
Pope, Joseph, 67
Priestley, Joseph, 60, 73
Prince, Nathan, 76
Prince, Thomas, 83
Princeton University (Nassau-Hall, College of New-Jersey), 6, 8, 14, 18, 28, 37, 52, 56–7, 65, 67, 71, 73–4, 75, 78, 85, 91
Ptolemy, 38, 47

Ray, John, 77
Rhetoric, 7, 9, 23, 24, 26, 27, 29, 31, 32, 33, 81
Rittenhouse, Davis, 20, 66, 67
Robie, Thomas, 44, 76, 83
Rohault, Jacques, 42, 66
Rowning, John, 64, 65
Royal Society of London, 3, 39, 40, 43, 44, 61, 80; *Philosophical Transactions* of the, 3, 44, 77
Rush, Benjamin, 72
Rutgers College (Queen's College), 89
St. John's College (King William's School), 6, 12, 92
Sewall, Joseph, 83
Shaw, 65
Silliman, Benjamin, 74
Simons, Lao G., 33
Simpson, Thomas, 55
Small, William, 61, 62, 86
Smallwood, W. M., 71
Smith, James, 72
Smith, William, 11, 22, 28, 29, 49, 55, 65, 66, 69, 72, 77
Spotswood, Alexander, 25
Stiles, Ezra, 19, 51, 66, 71
Stone, Edward, 53, 55
Strong, Nehemiah, 51
Tennessee, University of, 89
Torricelli, Evangelista, 65
Transylvania University, 6, 14, 83
Treadwell, Daniel, 53
Trumbull, John, 17
Turgot, Anne Robert Jacques, 86
Tusculum College (Greeneville College), 6, 13, 92
Tyler, Royall, 85

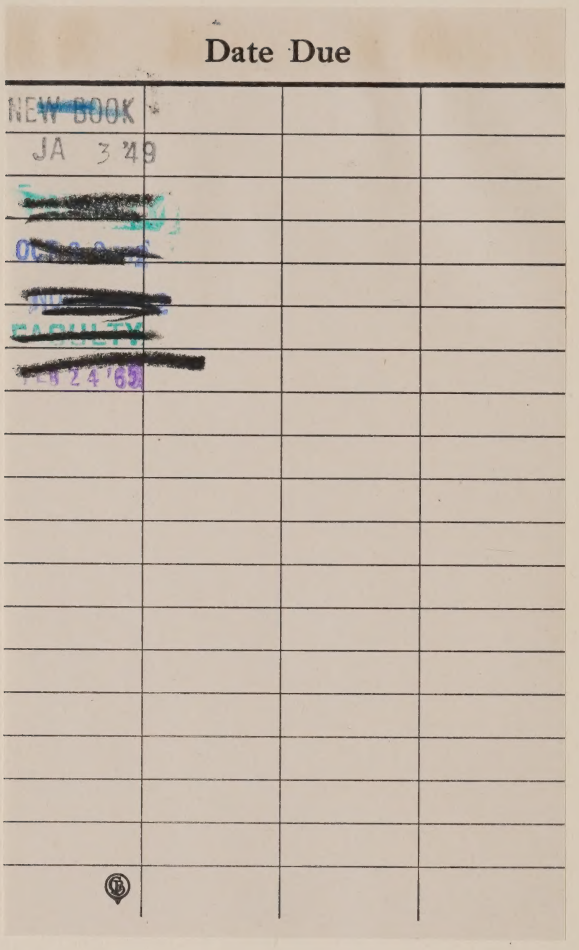
Union College, 6, 13, 92
Upsala Academy of Sciences, 3

Varenius, Bernard, 88
Vermont, University of, 89

Ward, John, 49, 52
Warren, Joseph, 88
Washington, George, 11, 85, 88
Washington College, 6, 11, 22, 29, 92
Washington and Lee University (Liberty Hall Academy), 89
Waterhouse, Benjamin, 70
Watt, James, 62
Watts, Israel, 60, 65
Webber, Samuel, 52
West, Benjamin, 53
Wheelock, Elezar, 11
Whiston, William, 43, 45
White, Andrew Dickson, 79
Whitefield, George, 82
Willard, Samuel, 83
Williams, Elisha, 42
Williams, Ephraim, 12
Williams, Samuel, 51–2
Williams College, 5, 12, 19, 92
Wilmington Academy, 20
Wilson, John, 55
Wilson, William, 53
Wilson, Woodrow, 86
Winnesborough, S. C., college at, 6
Winthrop, John (1606–1676), 37
Winthrop, John (1714–1779), 49–51, 57–61, 62, 74, 75, 76, 84, 86
Wistar, Caspar, 72–3
Witherspoon, John, 67
Wolf, Abraham, 3, 89
Woodhouse, James, 73
Woodward, Bezaleel, 52
Woodward, John, 42
Wythe, George, 61

Yale University (Collegiate School of Connecticut, Yale College), 6, 7, 14, 15, 17, 18, 20, 27–8, 36, 40, 42–3, 47, 49, 51, 66, 67, 71–2, 74, 75, 76, 77, 78, 82–3, 90–91

Zoology. See *Natural History*.


Date Due
NEW BOOK
JA 3 '49
FACULTY
FEB 24 '65

Q181 .H81
Scientific thought in the American
Princeton Theological Seminary-Speer Library
1 1012 00032 4519